PAPER TECHNOLOGY

A TYPICAL MILL (MECHANICAL OR GROUND WOOD PULP)

PAPER TECHNOLOGY

AN ELEMENTARY MANUAL

ON THE

MANUFACTURE, PHYSICAL QUALITIES AND CHEMICAL CONSTITUENTS OF PAPER AND OF PAPER-MAKING FIBRES

BY

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PREFACE

In consequence of numerous inquiries from students attending the courses of lectures on "The Manufacture and Uses of Paper" given in 1904–5 at the central Y.M.C.A., Exeter Hall, Strand, London, the author reproduces his lectures in book form, and offers the present treatise to stationers, printers, publishers, bookbinders and others as an elementary manual on the Technology of Paper.

While the author hopes that this book may be useful to the paper-maker, he has directed his attention, mainly, to a discussion of the subject for the benefit of those who use the paper. Numerous text-books have already been published dealing with the art of papermaking, but up to the present time no popular work has been issued in which the subject is treated along the lines suggested by this preface.

Discussion of the many important and highly technical details in connection with the manufacture of paper have therefore been omitted, as outside the scope of this work.

The author wishes to express his indebtedness to those who have supplied drawings and blocks for the purpose of illustrating this book, and amongst others Messrs. Bertrams Limited, Baird and Tatlock, James Bertram and Sons, T. J. Marshall and Co., Green, Son and Waite, W. Notman (Montreal), Louis Schopper (Leipzig), Waterous Co. (Brantford, Canada), Laurentide Pulp Co. (Quebec), J. Christie Esq., Professor Herzberg.

The author has attempted to make a glossary of the various qualities of paper known to the trade, and to give some notes as to the origin of the names used. It is very difficult to obtain precise and complete information as to many of the papers, and the author would feel grateful to his readers for any further information and correction which could be inserted in the next edition.

A complete glossary compiled in this way should be of considerable interest.

R. W. SINDALL.

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CHAPTER I

INTRODUCTION

Importance of the paper-trade—Lack of standards of quality—Deterioration of paper—Chemical and physical constants—Fibres in relation to the ideal paper—Principles of paper-making

The Paper Trade.—The subject of paper is one which interests a large number of people connected with industries which demand the use of paper and allied products. On the one hand is the paper-maker producing the finished article, and on the other hand there are the printers, publishers, bookbinders, paper agents and stationers, who supply the general public.

Of recent years there has been a good deal of agitation as to the inferior qualities of the paper used at the present day, and it is evident that much of the paper brought into the market will not last any length of time. It is quite true of the paper trade as of many other industries that the rage for cheapness has superseded the desire for an article of high quality, yet the paper-maker of the present day can produce a paper quite equal to any that has ever been made, for it is only a question of price. It is quite as unreasonable to expect a common writing paper costing *2d.* a lb. to have all the lasting qualities of a good writing paper costing *10d.* or *1s.* a lb. as it is to expect a *15s.* summer suit to last two or three seasons. The manufacture of good paper is by no means what some critics would be pleased to call a "lost art."

The purchase of paper is too often based on the qualities of appearance and price. There are apparently no standards of quality other than those of purely commercial consideration, so that in many cases the price paid is highest for papers made from the least valuable material.

In 1887 Professor Martens purchased seventy-eight different samples at random, but he found that only five of these samples were really up to the quality which might be expected, having regard to the description of the samples.

In 1894, Professor Herzberg, director of the Charlottenburg Institute, purchased thirty-five samples, asking for a good writing brief paper, but not stating any price. He found that only 17 per cent. of the samples could be considered really good, while 53 per cent. he characterised as being very poor.

Now it is a matter of common experience that some papers which appear to be satisfactory when purchased do not improve with use, and are quite incapable of withstanding the conditions which bring about deterioration both as to colour and strength.

Standards of Quality.—But so long as there is an absence of standards of quality this unsatisfactory state of things must continue. It may be traced partly to a want of interest in the subject, and partly to the lack of co-operation amongst those concerned. The keen competition amongst manufacturers which

has resulted in the creation of the false and arbitrary standards connected with the mere appearance of the paper is also another reason, whilst an indifference to the scientific aspect of the question has generally been the prime factor.

The discovery of substitutes for cotton and linen resulting in the production of cheap papers is probably responsible to some extent for this serious state of things. In 1887 Professor Martens examined no less than ninety-seven leading scientific and other journals, and found on classification the following results :

A. Rag papers with less than 2 per cent. mineral matter . .	2
B. Mixtures of rag and chemical wood with less than 5 per cent. mineral matter	2
C. Mixtures of rag and chemical wood, 5 to 15 per cent. ash. .	31
D. Mixtures inferior and containing ground wood . . .	62
	97

Deterioration of Paper.—In the case of many scientific journals the results of original research work had thus been entrusted to paper of inferior quality, and when the limited circulation of such journals is taken into account the matter at once assumes an importance which perhaps at first sight it does not deserve.

Another illustration of the great need for some decided step in the direction of standards of quality may be found in the law which compels the publisher of every book, journal and newspaper to send copies of these works to the British Museum and other public institutions. The historian of the future will be relying on the newspapers of the present day as the source of information for his writings, and it is obvious that these records, being merely ordinary editions of the common newspaper, are not sufficiently durable for the purpose which they are intended to serve.

The preservation of important documents thus becomes a matter of national concern, and it is somewhat surprising that so little has been done in this connection. It might also be noted that the durability of such documents not only entails a thorough investigation into the nature of the paper, but also an inquiry into the inks which are used, and their resistance to destructive agents.

The introduction during recent years of many varieties of coloured inks, particularly those used for typewriting or those advertised not to corrode the pen, has created a danger which cannot be ignored, namely, the tendency to the complete disappearance of written or printed characters owing to the use of fugitive colours which will not stand the action of the light.

No systematic work has been attempted in the direction of obtaining precise information as to the durability of paper or as to the lasting qualities of ink by any public body or authority, at least in England. A good deal of valuable work has been carried out from time to time by scientific men and experts in the course of their professional career, but the results of such investigations are only to be found scattered through the pages of scientific journals.

The whole subject, however, merits the attention of the Government, and there is no doubt that much good would accrue to the paper-maker, as well as the user of paper, if this question of standards of quality could be thoroughly inquired into.

Chemical and Physical Constants.—In considering the quality of a paper it is necessary to take into account:

1. The *Chemical* Constants, which term may be used as referring to the fibrous constituents, the mineral matter or loading, the colouring-matter, size, and other chemicals.

2. The *Physical* Constants, such as strength, elasticity, weight, resistance to wear and tear, bulk, opacity, &c.

At the Charlottenburg Institute in Germany the classification is made somewhat as follows:

Chemical Constants.	A. Celluloses from Cotton, Linen.
	B. Celluloses from Wood, Hemp, Jute.
	C. Celluloses from Esparto, Straw.
	D. Mechanical Wood.
Physical Constants.	A. Strength, breaking length.
	B. Elasticity.
	C. Tearing strain.
	D. Resistance to friction.

The only classification in England which defines the qualities of paper to any extent is that adopted by H.M. Stationery Office, the terms of which are summarised in the adjoined schedule:

No. 1. Air-dry writings. Mean breaking strain and stretch defined. Size of strip for testing stipulated.
No. 2. Ordinary writings. Machine-made, animal-sized. No particular strength defined. Paper to be free from fibre knots and hard particles.
No. 3. Blottings. To be made of rag, free from loading.
No. 4. Lithograph and printing papers. Papers to be machine-made, engine-sized, with not more than 15 per cent. of loading.
No. 5. Air-dry browns. To be machine made and air dried. Strip taken for testing to be 2 in. wide and 7 in. long.
No. 6. Cylinder-dry browns. Same as Class 5. The stretch of papers also specified.

The relative importance of the chemical and physical constants varies according to the nature of the paper. In some cases tensile strength comes first, as in *newspapers* and *cable papers*, the other qualities, such as appearance and finish, being of minor importance. In the case of *strong wrappings*, *bank-note papers* and *ledger papers* there must be high resistance to wear and tear, and to friction caused by repeated crumpling. Usually such resistance is found in papers possessing great tensile strength.

With *envelope paper*, *Bible papers* and *thin printings* the chief quality requisite is that of opacity, so that the writing or printing is not visible from the reverse side. In the case of such papers as *parchments* and *grease proof* the most important constant is that of resistance to air and water, so that these particular papers may possess the qualities implied in their description.

With *art papers* the only *qualities* which are particularly needed refer almost exclusively to the surface and finish of the paper, because it is desirable to obtain for the printing of half-tone blocks a paper of absolute surface. In the case of papers intended for *lithograph printing* it is important to obtain a paper which shows the least amount of expansion when moistened, because papers which are liable to expand to any extent cannot be used for colour-printing and litho work.

It follows from these few illustrations that paper must be studied: first, in a *general* sense, as to its nature, quality, and the constants already referred to; and, secondly, in a *particular* sense, as to the special purpose for which the paper has been manufactured.

This demands a study of the manufacture, particularly the modifications in the various stages of manufacture which give the desired qualities in the finished paper, the difficulties experienced by the printer and other users of the paper, and, finally, as far as possible, a reference back to the conditions under which it was made. A systematic study of these questions on the part of the *user* in conjunction with the *manufacturer* would go far to establish the most favourable conditions for the production of a paper answering all requirements.

For example, in the case of a litho paper the difficulties connected with the use of it are considerably reduced if the paper-maker is informed as to the manner in which the printer intends to work. It is well known that ordinary machine-made paper expands much more in one direction than in the other. This expansion is least in what is known as the *machine* direction of the paper, and greatest in the *cross* direction. If therefore a sheet is to be 24 in. by 12 in. the printer must exercise his judgment as to the cutting of the sheet and determine whether it should measure 24 in. in the machine direction or in the cross direction.

The Ideal Paper.—The ideal paper is one which possesses chemical and physical constants of a high order. Such constants make for permanence and utility, these qualities being more marked in papers manufactured from new rags.

The marked superiority of rag papers in point of quality is not a matter of chance, but is a function of the vegetable fibre itself which can be explained by reference to the chemical and physical composition of the raw material.

The term *quality* is unfortunately an ambiguous one, and frequently used as implying *suitability*, but the words are by no means interchangeable, since a particular paper may be specially suitable for a given class of work and yet be of very low quality. A common *box-enamel*, for example, may be a suitable paper, and in the ordinary use of the phrase "of good quality," but in the sense of having physical and chemical constants of real value may be of no quality at all.

The Principles of Paper-making.—The manufacture of paper involves a number of successive operations, each of which plays an important part in the production of properties required in any particular paper. The general principles underlying these operations are the same, whatever the original raw material or whatever the nature and quality of the finished paper. The variations of detail in certain specific stages of manufacture are naturally considerable, but a brief survey of the general outline of the process may be taken with advantage.

The stages of manufacture may be conveniently classified as follows:

1. The isolation of the paper-making fibre (cellulose) from the raw material.
2. The conversion of the cellulose into pulp, or "half-stuff."
3. The "beating" of the half-stuff.
4. The manufacture of the paper from the beaten pulp.
5. The processes relating to the finishing of the paper.

Isolation of the paper-making fibre from the raw material.—The nature and extent of the process by which the fibre is obtained from the raw material depends partly on the physical and chemical characteristics of the vegetable tissue and partly on the nature of the paper desired. For certain products, such as browns, wrappings, millboards, cardboards and the like, the preliminary treatment is so slight that the prepared fibre differs but little from the raw material, while, on the other hand, for better-class papers, such as those required for magazines, fine printings and machine-finished writings, which are mainly prepared from esparto and wood, the treatment is so severe that the fibre obtained has little in common with the raw material either as to physical structure or

chemical composition. With high-class rag papers, such as T.S. writings, ledgers, banks and loans, the severity of treatment is not in the preliminary process of isolation of the cellulose, but in subsequent mechanical operations, since the rags have already passed through certain stages of purification in the textile trade before reaching the paper-mill.

Generally speaking, the methods adopted for the isolation of paper-making fibre aim at the production of a more or less pure cellulose by digestion of the raw material with alkali or acid salts at a fairly high temperature. The alkali process is in practice applied to practically every commercial fibre, but the acid process is at present confined to the manufacture of chemical wood pulp.

Conversion of the cellulose into pulp, or "half-stuff."—The cellulose freed from the valueless organic compounds with which it is closely associated in the raw plant has then to undergo conversion into what is termed "half-stuff," a convenient name for the pulp when partially prepared. The boiled material, which usually retains its shape and general form even after the severe process of digestion, is mechanically disintegrated into single isolated fibres and in this condition the pulp obtained can be readily bleached. Straw, esparto and wood are easily broken up, whereas rags (cotton and linen), canvas cuttings (hemp), bagging (jute) require very prolonged treatment. The causes of such differences in behaviour will be understood by a study of the natural characteristics of the fibres. This initial disintegration produces "half-stuff" in which the fibres are merely teased out and prepared for the next operation.

The "beating" of the "half-stuff."—This is probably the most important stage in the manufacture of paper, and one in which the quality of the finished article may be varied to almost any extent. It is a common saying amongst paper-makers that "paper is made in the beating-engine," and a close study of the alterations in physical structure and constitution due to "beating" will at once show the importance of this operation.

For ordinary machine-finished papers, the sizing, loading and colouring of the pulp are effected at the same time and in the same appliances as the "beating" process.

For high-class hand-made and machine-made rag papers, the sizing is a separate process applied after the paper has been produced.

The manufacture of the paper from the beaten pulp.—The pulp is finally converted into paper by hand or by machinery, the proportion of hand-made paper being very small, only four or five mills in England being engaged in its manufacture. The industry is, however, an extremely important one, owing to the special properties of hand-made papers. All the preliminary operations in the manufacture of paper, whether hand-made or machine-made, up to this point are the same in principle, but the manipulation subsequent to the "*half-stuff*" stage varies according to the class of paper required.

The processes relating to the finishing of the papers comprise calendering, glazing, cutting, sorting, and packing. In addition to these operations of general application there are particular methods for producing such specialities as art, chromo, duplex and other papers.

CHAPTER II

TECHNICAL DIFFICULTIES RELATING TO PAPER

Specific examples of cases in actual practice—Influence of moisture—Wavy edges —Bulk—Uneven colour—Dust—Impurities

Specific Difficulties.—Many of the technical difficulties relating to the manufacture and use of paper are due to causes which may be readily explained. Problems of this kind, however, are usually dealt with by haphazard methods without any attempt to determine the exact cause of the trouble, with the result that the recurrence of the difficulty cannot always be guarded against. Many instances might be quoted to show that a correct appreciation of the factors relating to a particular defect would enable the printer to understand the reasons for the trouble which he experienced. A familiar instance of this is to be found in the well-known antique paper manufactured from esparto. The peculiar characteristic bulkiness of this paper is produced by beating the pulp under special conditions, but when the paper is used it gives a great deal of trouble owing to the production of dust and fluff on the printing-machine. The amount of dust can be reduced considerably by modifying the conditions of beating, but such alterations give a paper of heavier substance, less bulk and harder feel.

The difficulties experienced by printers and other users of paper are of two kinds. On the one hand there are defects general in character which may apply more or less to all papers of a particular class, and on the other hand there are troubles much more specific—which cannot be classified, because they are abnormal.

Thus the defect of *discoloration* in papers containing mechanical wood pulp is common to all such papers and its nature is well understood. The existence of minute transparent spots in a supercalendered printing may be quoted as an instance of a defect specific in character because the spots are not traceable to one general cause which accounts for every case. In the former case investigation as to the reason for discoloration is scarcely necessary, while in the latter it is essential.

The subject is obviously one of extreme importance as shown by examples referred to in the following sections.

The Influence of Moisture on Paper.—A study of the relation between fibres and moisture will explain many of the common difficulties relating to paper. A vegetable fibre is susceptible to atmospheric conditions in precisely the same way as other substances, altering in weight, dimensions, appearance and strength. The discussion of a few specific examples will illustrate this.

1. *Variation in weight.*—A sheet of paper taken direct from a paper-machine and placed on the Leunig scales may register 40 lbs. per ream, and when weighed after being posted to the stationer, a few days later, 42 lbs. per ream. Similarly, a sheet taken from the centre of a ream on arrival at the stationer's warehouse may register 40 lbs. and show 42 lbs. if left about freely exposed to air for several days.

The explanation of this difference is perfectly simple. Paper in a normal condition is capable of retaining 8 to 10 per cent. natural moisture, according to the time of year. When made on a fast-running machine at too high a temperature, it frequently contains only 5 per cent. Exposure of such paper results in the absorption of moisture from the air and a consequent increase in weight. As a matter of fact this is a most important point for makers of cheap news, who suffer considerable loss in this respect, as shown by Table I.

TABLE I.

Condition of Paper.	Per cent. moisture in the sheet.	Variation in weight due to contained moisture.			
		tons	cwts.	qrs.	lb.
1. Bone dry	nil.	90	0	0	0
2. Containing little moisture	4·0	93	15	0	0
3. As it comes off machine	5·0	94	14	3	0
4. " " . .	6·0	95	14	3	16
5. Containing more moisture	7·0	96	15	1	25
6. Moisture usual in dry weather .	8·0	97	16	2	0
7. " " damp " . .	9·0	98	18	0	0
8. " " " " . .	10·0	100	0	0	0
9. " " very damp " . .	11·0	101	2	1	22
10. " " " " . .	12·0	102	5	1	21

It is easy to see that a consignment of reeled news containing only 5 per cent. moisture weighing $94\frac{3}{4}$ tons at the mill could legitimately be invoiced at $97\frac{3}{4}$ under normal conditions. The margin is considerable.

2. *Creases in web news.*—The wrinkles, or "piping creases" as they are sometimes termed, frequently found in reeled paper are due to the presence of moisture. The paper leaving the hot drying cylinders is damped superficially by means of a fine water spray before being finally wound up. The water does not penetrate the sheet immediately, but only after the paper has been reeled. The natural expansion of the fibres caused by the moisture must have some outlet, and this usually takes the form of a wrinkle or crease in the body of the reel. The defect is seldom found in dry-reeled paper.

3. *Wavy edges.*—The difficulties relating to the "wavy edges" of paper occur in a variety of forms, being most frequently found in stacks of reams lying in the warehouse. The edges of the sheets gradually buckle and assume a wavy form, and when sheets are taken from the centre of the ream, they will not lie flat and even. Plate paper used for steel engravings is a familiar example of this defect.

Envelope papers exhibit a tendency to curl so that the envelopes cannot be handled. The usual remedy applied in such cases is to expose the sheets freely to the air, if wanted quickly, or to keep the paper in stock for a considerable time. The explanation of the difficulty is to be found in the fact that the edges of the sheets being exposed to the air, while the centres of the sheets are not exposed, expand by the absorption of moisture. The unequal expansion so produced "cockles" or twists the paper. Prolonged exposure gradually equalises the expansion and remedies the defect.

4. *Unequal register* in printing colours on lithographic paper is also due to expansion of fibres by moisture. During the interval elapsing between the several printings, the size of the sheet alters sufficiently in many cases to cause a serious error in "register." The paper-maker pays special attention to this class of paper as experience shows that those papers expand least in use which have

been made in such a way that the contraction of the wet sheet passing over the drying-cylinder of the paper-machine takes place naturally. The wet web on a paper-machine is subjected to a number of forces which tend to create a condition of unstable equilibrium amongst the fibres. Contraction and shrinkage continuously take place as the sheet passes over the drying-cylinders. The sheet is under constant tension while travelling from cylinder to cylinder. Any slight unevenness in substance will set up irregular drying. These factors have to be studied and allowed for in the manufacture of a good paper.

5. *Improvement in quality.*—Many papers are greatly improved by being kept in stock for a considerable period before use. High-class drawing and plate papers, strong wood-pulp wrappings, envelope, lithographic, animal-sized writings are typical examples of papers which are the better for being kept a reasonable time.

The improvement may be traced in most of these cases to the gradual adjustment of the cellulose to a normal condition, the fibre taking up from the air the moisture necessary to restore its "equilibrium," so to speak. The harshness and brittleness common to many papers when first made is gradually mellowed down by the absorption of moisture during storage.

With news, the quality and strength would be greatly improved if the printer was less particular about having a perfectly even white colour. The evenness of the colour and appearance of a common news is obtained, to a considerable extent, by sacrificing the strength through overdrying the paper.

The Causes which influence the "Bulk" of Paper.—The bulk of a paper is influenced by four main factors :

1. *The fibrous material.*—Of all the known paper-making fibres, cotton produces the bulkiest paper on account of its physical structure, the fibre having a tendency to curl and twist so that it will not lie flat. Esparto ranks second because it is a short cylindrical fibre which does not suffer much disintegration in the beater. Soda pulp is superior to sulphite in making paper of good bulk.

2. *The beating process.*—The treatment to which pulp is subjected in the beating-engine exercises a remarkable influence on bulk. Prolonged beating, lasting ten to twelve hours, with dull knives manipulated so as to draw out the fibres rather than cut them, makes a thin, hard dense paper, while quick beating with sharp knives for about an hour or an hour and a half will give a bulky, light and opaque sheet from the same pulp.

3. *The amount of mineral matter.*—Mineral matter, such as china clay or sulphate of barium, adds to the weight of a sheet of paper without materially increasing the thickness. If two papers are of equal bulk, the one containing loading, and the other not containing any, then the former will weigh more than the latter. This is due to the filling up of air spaces, the air in which has an inappreciable weight, by clay or loading which has an appreciable weight.

4. *The glazing.*—The paper after leaving the drying-cylinders has a rough surface and is very thick. The bulk is reduced enormously by calendering or plate glazing, the thickness being decreased by 30 or 40 per cent. The actual reduction depends upon the amount of pressure exerted, and the number of times the paper is rolled.

The differences between papers in respect of bulk are well illustrated in the following example :

	Thickness of Ream.
Antique	2·88 inches
Machine finished	2·21 "
Glazed	1·825 "
Extra rolled	1·68 "

These papers were all made of similar material and contained equal percentages of loading. Taking the substance at 45 lbs. double crown, and ash in papers at 10 per cent., with a small amount of rosin, the composition of the papers may be expressed in another form showing the actual amount of air space producing the amount of "bulk" in each paper. It is possible to express the composition of these papers in terms of the actual *volume* occupied by the fibre, ash, and air space:

TABLE II.

	Antique.	Machine finished.	Glazed.	Extra rolled.
Fibre	43·3	57·7	68·8	74·4
Ash	2·8	3·8	4·5	4·9
Air space	53·9	38·5	26·7	20·7
	100·0	100·0	100·0	100·0

The Deterioration of Paper.—This important subject cannot be adequately dealt with in a few brief paragraphs. It is due to a combination of two or more causes, amongst which may be mentioned:

1. Use of inferior celluloses or fibres.
2. Admixture of excessive quantities of mineral.
3. Excess of sizing matter.
4. Impurities left in during manufacture.
5. Atmospheric conditions.
6. Sunlight.

Papers containing mechanical wood become brittle, lose strength, and discolour very rapidly. This is due to slow oxidation of the non-cellulose constituents in the wood. Even traces of ground wood render a paper liable to decay. Papers containing straw and esparto cellulose are more resistant than those containing ground wood.

The admixture of excessive amounts of clay and similar loadings is scarcely a direct cause of decay, but since a corresponding increase of sizing ingredients is necessary to bind the mineral matter to the fibre, the power of resistance to deterioration is lowered. However, in the case of "imitation art," which is a soft sized paper, the lack of durability is directly due to the enormous proportion of clay, 30 to 35 per cent., which prevents the proper felting of the fibres.

Sizing ingredients, such as gelatine and starch, only produce a marked deterioration in paper under conditions which favour decomposition of the sizing material itself, namely, moisture in the air. The nitrogenous compounds in commercial gelatines are excellent mediums for the growth of many forms of bacteria. Rag papers sized with gelatine placed in stoppered bottles with a few drops of water and kept at a temperature of 80° Fahr. will rapidly exhibit micro-organisms of great variety.

Rosin size in paper acts indirectly as a cause of loss in quality by reason of changes set up by sunlight. Herzberg carried out some elaborate experiments in 1896, showing that light was the principal agent in bringing about loss of colour and sizing qualities in paper containing rosin size.

Impurities due to careless manufacture are a frequent source of trouble Incomplete removal of traces of bleach, of antichlors, or of free acid, frequently brings into the finished paper small quantities of residual chemicals, some of which are catalytic in action, that is, they induce chemical changes promoting

decay without being themselves permanently altered. The result of such action is gradual destruction of the whole body of the paper.

Atmospheric conditions affect paper differently according to circumstances. Papers exposed to impure air and fumes from burning gas gradually lose colour. Papers coloured or toned with aniline dyes are very sensitive to the state of the surrounding air in respect of moisture and chemical impurities.

The finish or surface of highly calendered papers is somewhat spoilt by moisture in the air. The fibres pressed down into an even surface by the calenders take up moisture and expand. This expansion produces a movement of the fibres from the surface of the paper and causes a loss of finish. Sometimes highly calendered news containing coarse fibres of ground wood when exposed to damp air loses its finish very materially since these fibres gradually rise up from the surface.

Sunlight has no direct influence on paper made from pure cellulose, but acts upon the non-cellulose constituents and added chemicals, and causes many of the changes already referred to.

Transparency of Papers.—The transparency of a paper is influenced by the kind of fibre used, the manner in which the pulp has been treated in the beating-engine, the amount of mineral matter added as loading, and the bulk of the finished sheet.

Sulphite wood-pulp beaten for a prolonged period produces the most transparent paper. The order of fibres with regard to transparency may be taken approximately as follows: sulphite wood, straw, rag, esparto, soda wood, jute, mechanical wood. The transparency is affected by the amount of boiling and bleaching, so that this order is by no means absolute.

Prolonged beating adds to the transparency of a paper, as may be seen by comparing a cheap wood-pulp printing paper with a wood-pulp writing paper. Pulp which has been beaten a long time does not part readily with the water and works "wet" on the paper-machine, whereas pulp beaten only for a short period allows the water to escape readily through the machine wire, working "free" as the paper-maker says. The latter condition favours opacity.

Loading affects transparency to a large degree. Two papers equal in other respects and loaded with 10 and 15 per cent of mineral respectively will exhibit different transparencies, the former being the more transparent. Treatment during supercalendering makes a paper transparent. If the surface of the paper is damped before glazing, the sheet is rendered still more transparent. The remarkable effect of pressure at the calender rolls is most easily observed with paper which has not been completely dried before glazing. In extreme cases transparent streaks appear in the paper, due to pressure on damp places in the sheet.

Unevenness of Colour.—Coloured papers frequently exhibit a marked difference in the colours of the two sides.

Papers coloured with ultramarine or similar pigments will sometimes show a lighter shade on the upper surface, and sometimes on the under surface. These defects are largely due to the action of the vacuum boxes on the paper-machine, which exert a powerful suction on the under surface of the paper when extracting the water from the pulp. Too much suction tends to draw out the fine particles of pigment and produce a lighter shade of colour on the under side of the paper.

Some aniline dyes also exhibit this peculiarity, but from different causes. The colour is not due to suspended particles of insoluble pigments, as the soluble dye is precipitated in the pores of the fibres. The change in colour often seen in aniline-coloured paper may be attributed in some cases to the action of the heat of the drying-cylinders on the sensitive aniline compound,

Wood papers when calendered often appear very irregularly coloured, and the surface looks mottled. Sulphite and mechanical pulps possess very different affinities for aniline dyes, the latter being coloured readily. The dyeing of mixtures of wood-pulps is an art in itself.

Dust from Paper.—The dust which gradually accumulates on the type of the printing press may be due to a variety of causes.

In the manufacture of web news the sheet leaving the calenders of the paper-machine sometimes rubs against a stationary guide roll before being finally reeled up. The friction causes an accumulation of small fibres and mineral matter at the point of contact, and the accumulated dust comes away periodically with the sheet; when the reel is used at the printing office the dust gives trouble. This defect does not often occur.

The fluff from news is sometimes due to the use of mechanical wood which is coarsely ground. The coarse chips lie on the surface of the sheet and are pressed in by the calender rolls. The friction of the rolls on the printing-machine is sufficient to release many of them and so the type is soon fouled.

Coated papers are a fruitful source of trouble in filling up type and electro blocks. The defect usually arises from an insufficiency of glue in the coating mixture.

Bulky featherweight and antique papers produce fluff on type. The fibres are only loosely felted together in such papers and friction causes the smaller fibrous particles to come away very easily.

Impurities in Paper.—This important subject deserves careful attention, because many of the difficulties experienced by printers arise from the presence of impurities in paper. An interesting treatise dealing with specific cases arising during the course of professional practice could be written, and such a book would prove of considerable value. It is impossible to do more than give a brief account of a few actual instances, which the author has had occasion to investigate.

Fibre.—1. One of the most frequent troubles common to newspaper is the breaking of the sheet when passing through the printing machine. With a production of 24,000 copies per hour the loss of time occasioned by an unnecessary break is considerable. In most cases the break may be traced to the presence of coarse fibres or of thin hairs near the edge of the reel, lying at right angles to the direction in which the paper is travelling on the machine. A microscopic examination of the fibre will reveal its nature and determine whether it is a coarse fibre from the pulp or some adventitious substance, such as string.

2. An esparto paper made light and bulky contained some coarse particles which closely resembled mechanical wood when examined with the eye. The microscopic test proved them to be undigested pieces of esparto fibre which by some means had found a lodging-place in the paper.

Acid.—1. Some papers were rejected because they gave an acid reaction with litmus, the extract obtained by treating them with water turning blue litmus papers red. The investigation showed that the papers did not contain any free acid, but merely sulphate of aluminium, which turns blue litmus red. Litmus paper is not a reliable test for free acid.

2. The pages of a novel were found to be disintegrated, the paper crumbling to powder when rubbed between the fingers. This was due to sulphuric acid with which the novel had by some means come into contact. Some of the other pages in the book proved to be normal high-class rag paper.

Particles of dirt.—1. Samples of some common pastings were examined for particles of dirt, many of which fell out of the sheet when the paper was handled, the holes produced causing considerable trouble when the sheet was pasted. The dirt proved to be coarse particles from the china clay used as a loading for the

paper. The clay had not been carefully mixed with water and strained before use.

2. In some cardboards made by pasting two sheets of paper together some greasy yellowish coloured spots of varying size were found, and at first attributed to faulty paste. Investigation proved this assumption to be incorrect, the defects being due to greasy matter dropping into the pulp on the paper-machine.

3. Brownish spots in a photographic mount which were only rendered prominent after pasting were carefully examined, and proved to be minute particles of iron rust, and not a growth of some micro-organism as supposed.

4. Some black specks in a sheet of supercalendered paper were examined and reported as coal. Subsequent inquiries at the mill confirmed this opinion.

Smell.—1. A ream of paper when opened at the warehouse gave off a most unpleasant odour, which gradually disappeared when the sheets were spread out. The smell closely resembled that of sulphuretted hydrogen, and it was found that the paper contained sulphur compounds.

2. Some art paper having an unpleasant odour was found to have been prepared with glue of poor quality.

Mineral matter.—1. A blotting paper of poor quality, which became non-absorbent after being used a few times, was found to contain lime salts deposited from the hard water with which the rags had come into contact before and after conversion into pulp.

2. A paper guaranteed to have been manufactured without the addition of mineral matter was tested for china clay, which was present to the extent of 2 to 3 per cent. This was eventually traced to the fact that waste papers used in furnishing the beater contained china clay in quantity sufficient to account for the above proportion.

CHAPTER III

RAG PAPERS

Preliminary operations.—Sorting, cutting, dusting, boiling, washing—Bleaching—Half-stuff—Beating. *Hand-made papers.*—Description of process—Tub-sizing—Preparation of animal size—Drying—Plate-glazing. *Machine-made papers.*—The Fourdrinier machine

Preliminary Operations.

Rags.—The rags used for paper-making consist of a great variety of materials, from new linen and cotton cuttings produced in the factories devoted to the making of wearing apparel, to old, worn and dirty rags which have been discarded from domestic service as useless.

The rags collected by the merchants who supply the paper-mill are not mixed indiscriminately, but are properly sorted out into different qualities, so that the paper-maker can obtain the particular grade of raw material best suited to his purpose. Even then the rags are submitted to a second sorting process at the mill, since the quality of the finished paper depends very much upon the condition of the rags. A high-class linen paper cannot be made satisfactorily if the stuff used contains varying proportions of old and worn rags, more or less cotton. The production of a first-rate blotting can only be ensured by a rigid exclusion of all rags except those which experience has proved most suitable.

Qualities of Rag.—The classification of rags is usually an elaborate process based on certain broad distinctions as to the nature of the fibre, the colour of the rag and its condition. The sorting is thus carried out with due regard for

1. The Material.	Linen. Hemp. Cotton. Wool.		
2. The Colour.	Whites, first and second.		
	Colours, red, blue, grey.		
	Neutral, blacks and dark colours.		
3. The Quality.	Classification somewhat as follows :		
Cottons.	New cuttings.	*Linens.*	Fine whites.
	Worn whites.		Coarse whites.
	Soiled whites.		Seams and hems.
	Unbleached cottons.		Soiled whites.
	Blue checks.		Seconds.
	Muslins.		Thirds.
	Cord.	*Hemps.*	Canvas.
			Rope.
			Waste.

The extended nature of the various grades into which the rags are divided both by the merchants for the purpose of sale, and by the paper-maker for manufacture, can easily be gauged by a glance at the market reports of the paper-trade press.

Sorting and Cutting.—The rags arrive at the mill packed in huge bales, and are then put through a preliminary *dusting* to remove the greater portion of

any dirt. The duster consists of a long hollow cylinder covered with very coarse wire, inclined at an angle, so that as it revolves the rags thrown in at the upper end travel towards the lower end and discharge themselves free from any loose dirt.

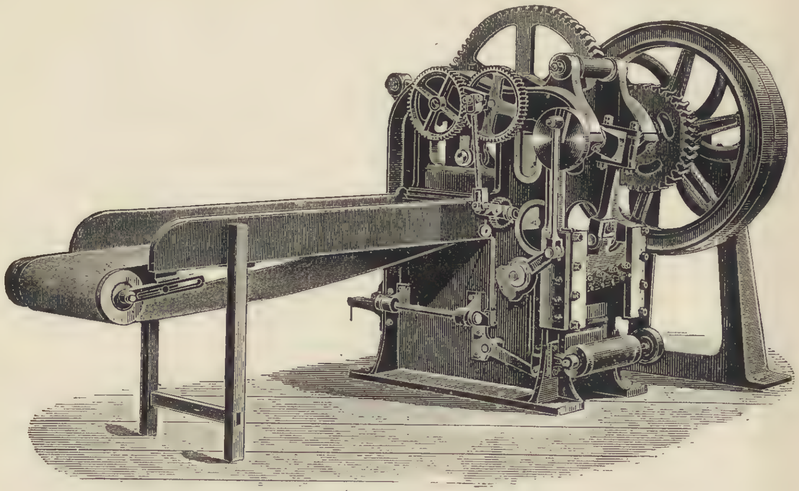


Fig. 1.—Nuttall's Patent Rag Cutter.

The rags are then distributed to the various sorting-tables, where buttons, hooks and eyes, leather, rubber and other foreign matter likely to injure the quality of the pulp are carefully removed. The rags are cut by women into long slips, and these again reduced into pieces about four inches square. The cut rags are then finally sorted up and thrown into boxes or baskets placed round

Fig. 2.—Rag Willow and Duster

the sorting-table, great care being exercised to keep old and new rags separate, to differentiate the material as to colour and cleanliness, and to preserve uniformity in quality.

Hand-cut rags dealt with in this manner are much more expensive than machine-cut rags, but for high-class paper the latter do not give the best results.

A rag chopper consists of a pair of revolving cylinders carrying one set of

knives which cut the rags into shreds of convenient length, and another set of knives for cutting the shreds into short pieces. There is a greater loss of fibre with machine-cut rags, and the pieces are always very irregular in shape, which is a disadvantage in manufacture. The cut rags are next passed through a dusting-machine known as a "Willow." This machine consists of an iron drum provided with long iron spikes, or teeth, which revolves rapidly inside a closed box, the interior of the latter being provided with similar iron spikes. The rags are thus thoroughly loosened and opened up, the dust and dirt falling through a wire grating below the box. In addition to the drums, the Willow contains a duster similar to that already described, by means of which the rags are completely and finally freed from all impurities of a mechanical nature.

It is estimated that the loss of weight sustained by rags in dusting varies from 1 to 6 per cent., according to quality.

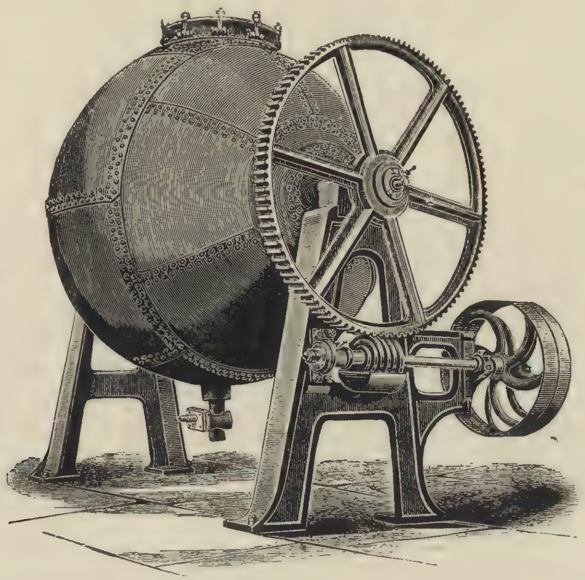


Fig. 3.—Revolving Spherical Boiler.

Boiling.—The clean rags are next boiled with chemicals to remove fatty and greasy matters, and to dissolve out all substances, such as starch and size, which may be present. The usual process involves the employment of caustic soda, caustic lime, or a mixture of lime with carbonate of soda, which substances are placed in suitable digesters with the rags in definite proportions.

The digesters used are either cylindrical or spherical in shape, 7 to 9 feet in diameter, mounted on suitable trunnions so that they can be rotated slowly. A charge of from two to three tons of rags is thrown into the digester through a man-hole, which is then bolted down. The solution of caustic soda is passed into the boiler through the hollow trunnion and, finally, the steam is admitted through the other trunnion. The conditions under which the rags are boiled vary at different mills, since the factors which determine the process may be altered as required. These factors are: the strength of the liquor, the pressure of steam and the period of boiling. The object of the process is the formation of soluble compounds by the action of caustic soda on the foreign matters in rags, which themselves are insoluble. The soda combines with these to form a soap,

which is subsequently washed out. This action becomes more complete and is hastened by using a fairly high steam pressure or by the employment of strong caustic soda.

The proper adjustment of the amount of caustic, the steam pressure, and period of boiling so as to produce a maximum yield of boiled rag of good colour at a minimum cost is naturally a question which calls for considerable technical skill and practical experience.

The time of boiling varies from three to seven hours, the steam pressure being between 15 and 30 lbs. to the square inch, and the proportion of caustic soda 5 to 8 per cent. on the weight of rags treated.

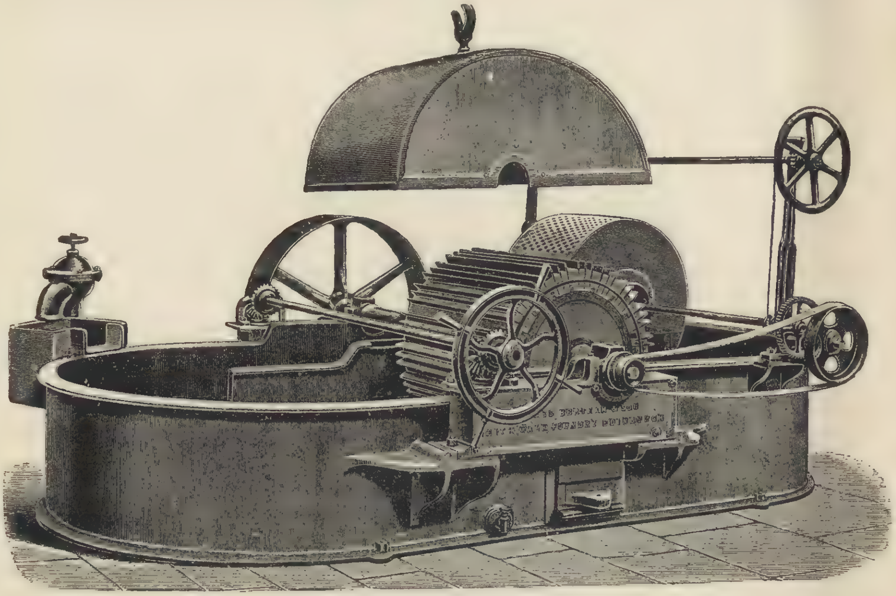


Fig. 4.—Rag Breaking and Washing Engine.

After the boiling is finished the steam is turned off, and the pressure reduced by blowing off. The man-hole cover is removed, and the rags discharged into the tank on the floor by allowing the boiler to rotate as before.

There are one or two interesting modifications of this operation worth noting.

In certain cases, when there is a demand for paper prepared without the use of any chemicals, rags can be treated by boiling in an open pan with pure water. Naturally this is only possible when the rags are absolutely new and free from any grease to start with, for the manufacture of paper is then almost entirely a mechanical process. The colour of the paper obtained without the use of caustic soda and bleach is somewhat lower than that of paper produced in the ordinary way.

A method of boiling rags by an apparatus known as the "Mather Kier" has been introduced of recent years, though it has not been largely adopted.

The rags are packed into small iron trucks, which are pushed along rails into the kier, a long oval-shaped vessel resting on the floor. The door of the kier is closed, and the caustic soda solution pumped in and kept in continuous circulation while steam is admitted at a pressure of 10–12 lbs. per square inch

for three to four hours. The door is opened after the pressure has been released, and the rags are quickly withdrawn for washing.

It is estimated that the loss which rags sustain when boiled is as follows:

Cottons	4 to 14 per cent.
Linens	7 to 24 per cent.

It is impossible to fix an average figure representing the loss due to boiling, as the amount depends on the quality of the rag.

Washing.—The rags discharged from the boiler vary in colour from light brown to black according to the proportion of impurity present in the material originally taken, the dark colour being due to the action of the caustic soda. The impurities being mainly in a soluble form are then washed out, a process which takes two to four hours and consumes a large quantity of water. The apparatus almost universally employed is that known as a "breaker." It is an oval-shaped vessel divided into two channels by a "midfeather" or partition which does not reach from one end of the vessel to the other, but merely occupies a central position. In the bottom of one channel is fixed a "bed-plate" containing fixed steel knives, and immediately above the bed-plate is a heavy cast-iron roll suitably mounted on bearings, which roll is provided with a number of steel knives. The floor of this channel slopes upwards gradually towards the space between the stationary bed-plate and the heavy roll, and falls away very sharply at the back of the roll. This peculiar construction of the machine is an essential feature of its action on the stuff, because when the breaker is loaded up with its proper complement of water and dirty rags, a continual circulation of the stuff round the engine is maintained owing to the formation of the "back-fall" behind the roll. In the other channel there is a "drum-washer" for the removal of dirty water. This consists of a hollow drum provided internally with curved partitions or buckets, and covered externally with fine wire-cloth. The drum-washer can be raised or lowered at will, and when lowered it is driven from the main shaft of the heavy roll (*see* Fig. 4).

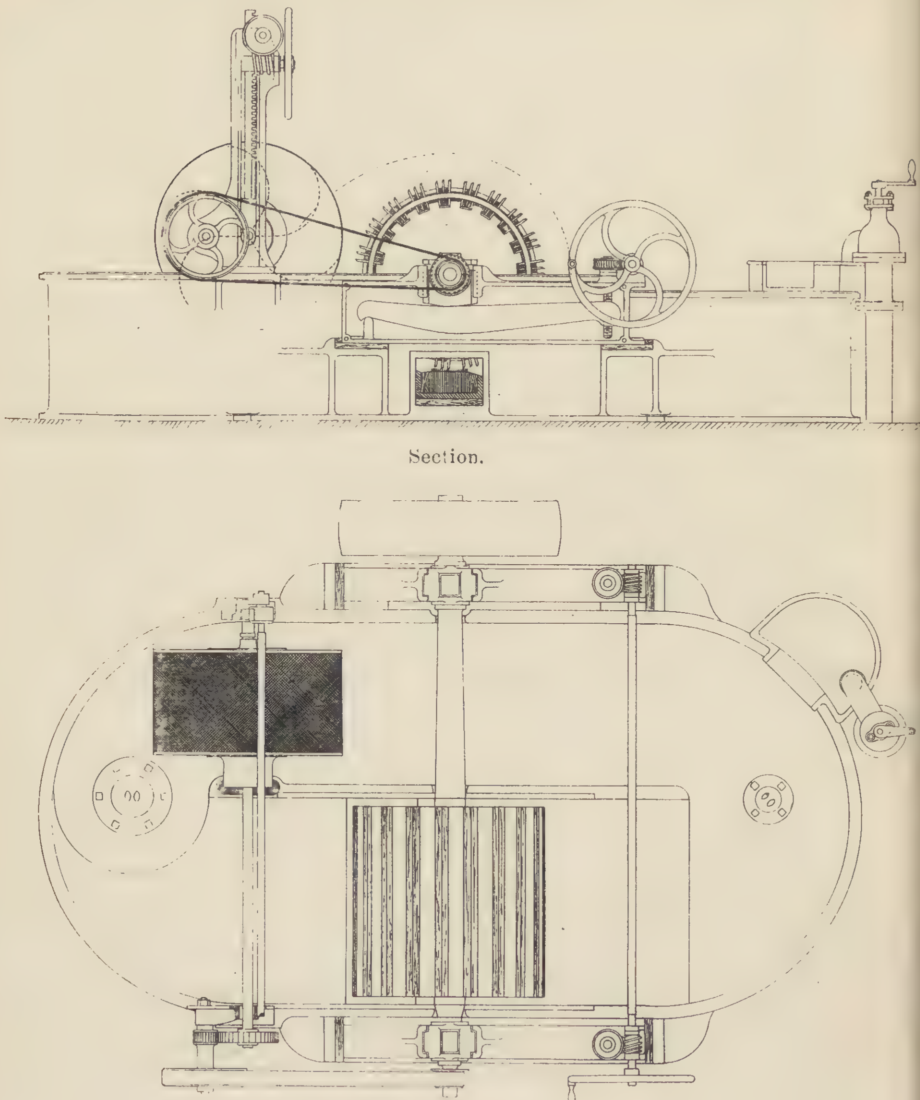
The engine or breaker is three-parts filled with clean water, and the rags shovelled in from small trucks previously loaded up in the digester house. As soon as a sufficient quantity is thrown in the drum-washer is lowered. The rags are drawn in between the rapidly revolving roll and the stationary bed-plate, being partially disintegrated and opened out; the impurities mix with the water, which quickly becomes dirty and foul. The dirty water finds its way into the washer and is raised by the curved buckets of the drum to the centre and discharged into a special trough connected with suitable outlet pipes which carry the water away. Meanwhile a continuous supply of clean water is fed into the breaker and gradually the dirt is washed out of the rags, which rags at the same time are broken up from the condition of square pieces to that of single threads, which are more or less matted together.

As the amount of water necessary for the complete washing of boiled rags is very large, the importance of the purity of the water-supply cannot be overrated. It is estimated that to make one ton of finished paper no less than 50,000 to 70,000 gallons of water are required. As this enormous quantity comes into contact with the rags it is obvious that any suspended solid particles of dirt will adhere to the pulp and eventually "show up" in the paper. Nearly 50 per cent. of the total amount of water used is required for this process of washing.

Bleaching.—The washed rags are brought up to the necessary white colour by the use of chloride of lime, or bleaching powder, as it is more commonly named. This powder, on being stirred with water, gives a greenish coloured solution of calcium hypochlorite having a pungent odour of chlorine, while about 16 per cent. of the powder, which consists of lime and chalk, settles to the bottom

of the vessel as a sediment. Only the clear bright liquor is actually used for bleaching.

There are many systems in vogue for bleaching fibres. In the case of rags it



Section.

Plan.

Fig. 5.—Rag Breaking Engine.

is a frequent practice to bleach the pulp in the breakers, the drum-washer being raised out of contact with the rags, and a definite quantity of strong bleach liquor added to the rags from a stock tank. The rags are kept in motion and gradually the bleach acts upon them until the colour is attained. When the

colour is sufficiently good, the drum-washer is lowered and the rags thoroughly washed free from the residual bleach liquors.

The efficient bleaching of rags, and indeed of all fibres used for paper-making, is a subject of the highest technical importance, but a complete discussion of the many conditions which need to be studied would be somewhat out of place in the present treatise, so that it is only necessary to indicate sundry modifications of the process.

The best colour is obtained with rags when, after the requisite amount of bleach has been added, the whole contents of the breaking engine are discharged into a brick or cement tank and allowed to remain sixteen to twenty hours until the whole of the bleach has been exhausted.

The process of bleaching is sometimes hastened by heating the contents of the breaker with steam, the hot bleach acting more energetically upon the pulp; but, unless great care is exercised in regulating the temperature, the fibre itself is attacked, and the ultimate colour may be liable to "go back," as it is called.

Half-stuff.—The bleached pulp after washing is discharged into cement tanks or drainers, which, being provided with perforated false bottoms, allow all the surplus water to run off. The moist pulp at this stage is known as "half-stuff."

The loss sustained in the preparation of the half-stuff during the various operations for certain classes of rags is given in Table III., but the figures can only be regarded as approximate, since it is impossible to give absolute results with a classification dependent on sorting, a process which is merely arbitrary and a matter of convenience.

TABLE III., *showing percentage of Loss on Rags during Treatment.*

Rags.	Sorting.	Cutting.	Boiling.	Breaking and Bleaching.	Total loss.	Yield of bleached half-stuff.
English New Cuttings . .	0·5	1·0	6·0	4·5	12·0	88·0
Cottons No. 1	0·5	1·0	7·0	5·5	14·0	86·0
Unbleached Cotton . . .	0·5	2·0	13·0	8·5	24·0	76·0
Linens No. 1	0 5	2·0	8·0	5·5	16·0	84·0
Linens No. 3	1·0	2·0	12·0	9·0	24·0	76·0
Unbleached Linen . . .	0·5	2·0	18·0	15·5	36·0	64·0

Beating.—The half-stuff, thoroughly washed free from all residual chemicals likely to spoil the quality of the finished paper, is next submitted to the process of beating. The long stringy mass of fibres which compose the half-stuff must be completely disintegrated into single individual fibres, and cut to the requisite length. The rationale of this most important operation and the effect of varied conditions of beating are more fully dealt with in the chapter devoted to the subject of beating, so that a mere description of the actual treatment of the rag half-stuff at this stage will suffice.

The rags are generally beaten in the old-fashioned "Hollander" engine, a machine which has no rival in any of the modern beaters for the efficient treatment of cotton and linen half-stuff. The engine is first partially filled with fresh water or with "backwater" from the paper-machine. This backwater drains away from the endless wire of the machine, and, containing a considerable proportion of fibre, is utilised over again in order to save the loss which would otherwise take place. The rag stock is added to the water in the beater gradually until the engine is properly filled with a thick mass of pulp of the

right consistency. During the filling-in the beater roll is kept well off the bed-plate to permit of ready and rapid circulation of the stock.

As the fibres separate out the roll is gradually lowered from time to time to suit the class of paper required. In the case of high-class rag paper the process is a long and tedious one, occupying from eight to ten hours, consuming a great deal of power.

For the best qualities of rag papers the use of the beating engine is practically confined to the actual reduction of the half-stuff to suitable pulp. The toning of the pulp with such pigments as ultramarine, prussian blue, smalts, or some vegetable dye is, however, effected by adding the desired colouring-matter to the stuff in the beater, but beyond this no further operations are carried out until the beating is finished.

When the pulp has been sufficiently treated, which the paper-maker can judge by taking out a small quantity of the stuff and stirring it into a large

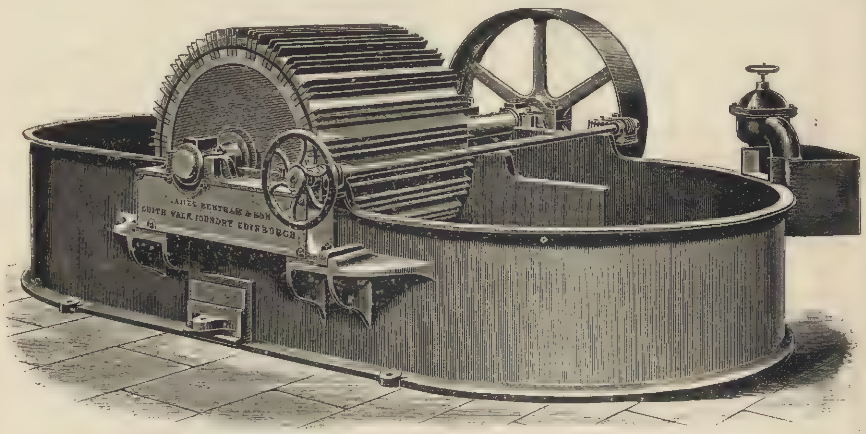


Fig. 6.—Beating Engine, with Cover removed to show Beater Roll.

volume of water so that the condition of the fibres may be examined, the contents of the engine are discharged into a *stuff-chest*, which forms the stock-tank for the pulp now ready to be converted into paper.

For the commoner qualities of rag papers, a mixture of rag pulp and wood pulp is frequently used, and the two beaten together. A certain proportion of some mineral matter, or loading, as it is termed, is also added to the pulp and thoroughly incorporated with the stock in the beater. China clay, sulphate of lime or blanc fixe are the more commonly used fillers, and they are added to the engine either in the form of a dry powder or as a thin creamy paste previously prepared by mixing the powder with water.

Such common papers as these are also frequently sized with a small proportion of rosin size which is added to the pulp in the beater. A complete description of this process of "engine-sizing" is given in chap. iv.

The beaten pulp in the stuff-chest forms the stock from which the paper is made by hand or by machine.

Hand-made Papers.

The manufacture of paper by hand from the "vat" is an operation which can be described readily enough, but the actual manipulation of the beaten pulp demands considerable skill and practice.

The formation of a sheet requires the work of three men, each with specially defined duties: the "vatman," who dips a mould into a vat containing the beaten pulp and makes the sheet of paper; the "coucher," who transfers the wet sheet from mould to felt and builds up the pile or "post" of alternate wet sheets and felts; the "layerman," who detaches the moist sheets, after they have been pressed, from the felts.

The mould is a wire-cloth stretched on a large wooden frame, the cloth being supported by stout wire, which is in turn kept rigid by wedge-shaped pieces of

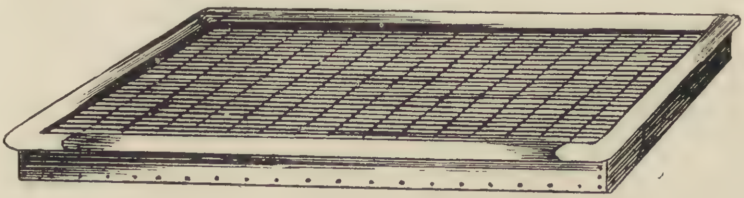


Fig. 7.—Mould for making "Laid" Paper.

wood. The size of the frame varies according to the sheet of paper required, the largest being one used for the manufacture of *Antiquarian*, which measures 53 inches by 31 inches. The great weight of the mould and sheet required for this large size compels the attention of six men in place of the three usually employed to each vat.

The mould is provided with a movable frame known as "a deckle," which fits closely to the mould and forms a narrow rim, so that the apparatus resembles a shallow tray, with a wire-cloth bottom.

The "vatman," holding the mould by its short sides, dips it into the vat containing the pulp mixed with the suitable amount of water, and withdraws it,

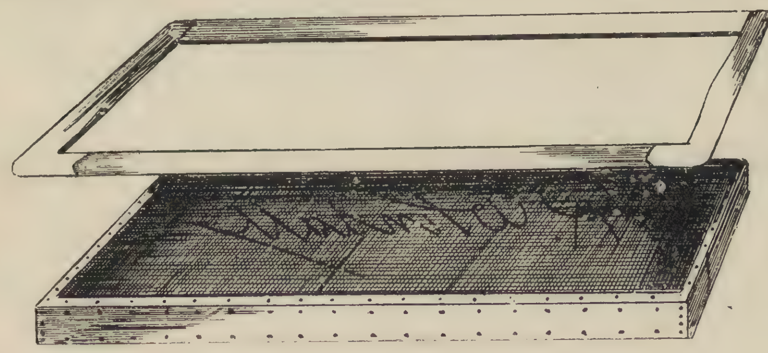


Fig. 8.—Mould for making "Wove" Paper.

taking up sufficient pulp to make a sheet of the required substance and thickness. The mould is shaken to and fro, and from side to side, in order to produce a felting or interlacing of the fibres, so that as the water gradually drains away through the wire-cloth, the fibres settle down on the surface into a sheet of paper. The various motions imparted to the mould demand great care in order that the successive sheets may not vary beyond reasonable limits as to their substance, thickness and strength.

When the water has drained off sufficiently, the vatman lays the mould upon an inclined board, which allows a further quantity of water to get away, and

removes the deckle to a second mould, with which he proceeds to make the next sheet of paper.

The coucher then, taking up the first mould, turns it over and presses it against a felt, so that the wet sheet of paper adheres to the felt, after which he returns the empty mould to the vatman, covers the sheet just transferred with another felt of suitable size, and is then ready to "couch," as it is called, the second sheet prepared by the vatman.

A pile or "post" of sheets is thus formed, consisting of wet sheets alternated with felts, and when completed it is subjected to heavy pressure in order to remove all the water possible, and to produce a firmer sheet of paper.

The layerman separates the moist sheets of paper from the felts, and the paper is again put into the press. In some cases the quality of the paper is improved by mixing the moist sheets from one pile with the moist sheets from a second pile, so that a third is produced. If this third pile is submitted to a second pressing operation a more uniform result is obtained.

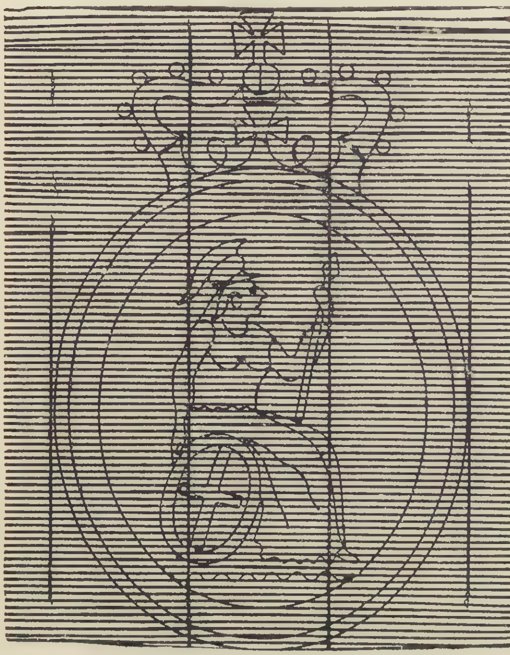


Fig. 9.—View of a "Laid" Wire with Design for a "Water-mark."

Water-mark.—The watermark in a sheet of paper is obtained when a raised design or pattern made of thin wire worked into the required shape is fastened upon the surface of the wire which forms the mould. The layer of fibres over every portion of the design is thinner than the surrounding layer which forms on the surface of the mould in the ordinary way, and the design appears as a transparent pattern in the dry paper.

Water-marks were used in the early days of paper-making, and many well-known sizes of paper owe their names to the typical water-marks, as, for example:

Water-mark.	Name.	Size.
A hand with star	Royal hand .	25 inches × 20 inches.
Jester's cap or figure of jester's head .	Foolscap .	17 ,, × $13\frac{1}{2}$,,
Postman's horn	Post . .	19 ,, × $15\frac{1}{4}$,,
Tankard	Pott . .	15 ,, × $12\frac{1}{2}$,,

The wet paper is hung up in drying-rooms, or lofts, and allowed to dry by exposure to the air, the evaporation of moisture being hastened in most cases by a supply of heated air, or by means of steam pipes fastened to the floor of the loft.

The dry paper at this stage is known as *waterleaf*, being more or less like

blotting paper, with a rough surface, and possessing very little of the strength of the finished sheet. It is highly absorbent and instantly soaks up any moisture with which it comes in contact.

The Sizing of Rag Papers.—The dry paper taken from the drying-shed or *loft* is known as *waterleaf*, being very absorbent, and closely resembling blotting paper in its capacity for taking up water or ink. This waterleaf is sized in order to give it a surface which will resist moisture and carry ink without penetration. Hand-made paper is sized with gelatine, sometimes called animal size, while other qualities of rag paper are partly rosin-sized and partly tub-sized.

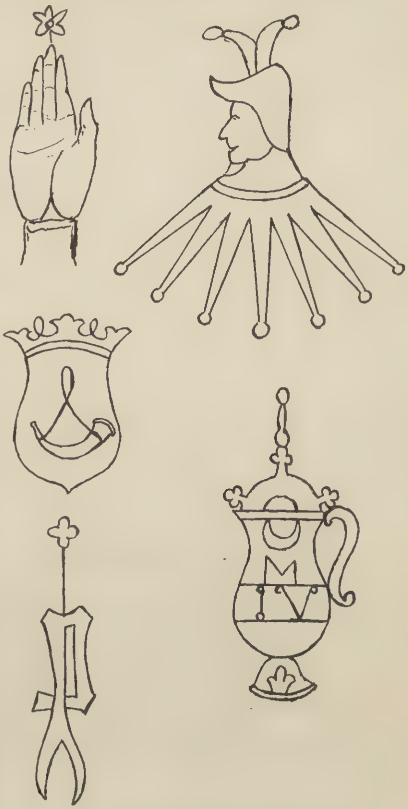


Fig. 10.—Some Water marks used in the Early Days of Paper-making.

The sheets are dipped, a few at a time, in a tub or vat containing a solution of gelatine, the temperature of which varies from 90° to 110° Fahr. After a slight immersion the sheets are taken out, reversed, and dipped a second time in order that the corners held by the sizeman may be duly sized. The surplus solution is pressed out of the sheets, which are then hung up to dry. The wet sheets are sometimes stacked up for several hours before being suspended, as the paper is better sized by this procedure.

Several modifications of this early and primitive method of sizing are now in common use.

For example, the sheets of waterleaf are thrown upon a travelling felt, which is drawn through a long vat or trough containing the hot size solution.

The size penetrates each sheet of paper, and as the fel, reaches the other end of the trough it carries the sheets of paper between a pair of squeezing-rolls which remove any surplus size. The sheets are stacked up and carried to the drying-room.

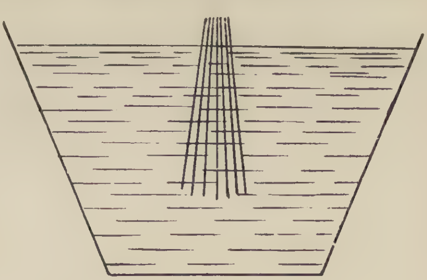


Fig. 11.—Diagram to illustrate Tub-sizing by Hand.

Animal Size.—The term "tub-sizing" or "animal-sizing" is applied to the treatment of paper by means of gelatine and glue, the former because the sheets of paper are dipped into a tub containing the solution of gelatine, and the latter term being used because gelatine is an animal product.

The gelatine is prepared from hide-pieces, horns, bones, sheepskins, and the feet of animals.

Hides and Skins are thrown into clean water to remove blood and impurities, and then cut into convenient-shaped pieces, which are again washed in a

drum revolving in a tank of water. They are next heated with water in a steam-jacketed pan, great care being necessary to employ the temperature best suited to the quality of the raw material. The pieces gradually dissolve,

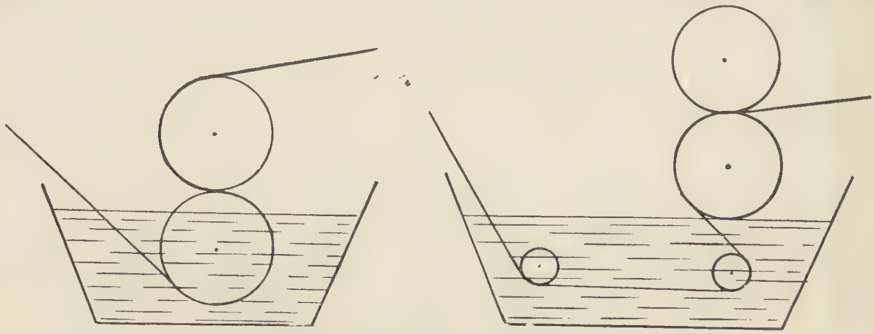


Fig. 12.—Diagram to illustrate Tub-sizing by Machinery.

any dirt or lumps falling to the bottom of the pan, and the hot gelatine solution is drawn off through cloth into stone tanks, a small proportion of alum being added to arrest putrefaction. The percentage of pure gelatine obtained

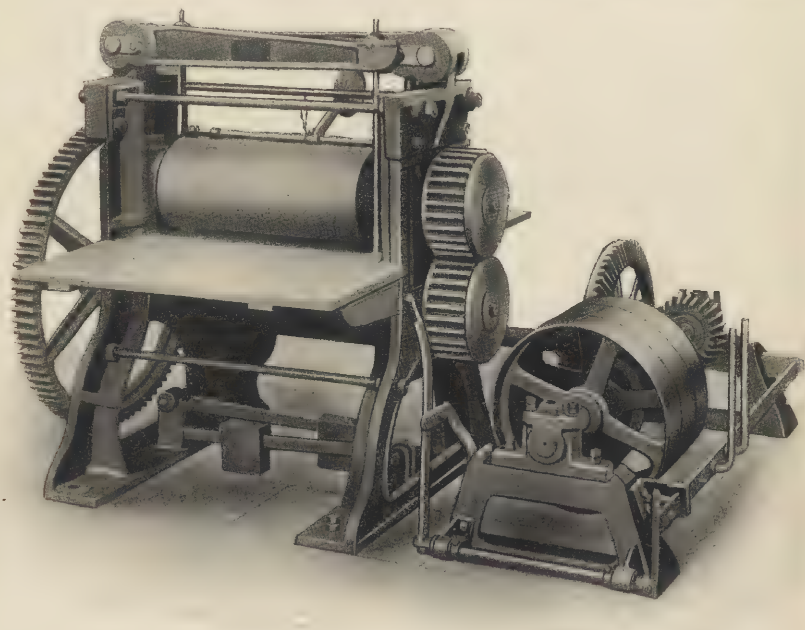


Fig. 13.—Plate-glazing Calender.

from ordinary wet hide-pieces is about 13 per cent., the exact proportion depending on the amount of moisture in the raw material.

The conversion of bones and horns into gelatine is not quite so simple. The

material is first treated with hydrochloric acid, to remove the lime phosphates, leaving the "cartilage" which yields the gelatine. This "cartilage" is boiled with water in a steam-jacketed pan and the solution clarified and run off into stone tanks with alum in the usual way.

Leather pieces yield gelatine of low colour and poor quality.

Drying.—The sized sheets are hung up in the *loft* on poles or cords and simply dried by exposure to the air, which is sometimes warmed to hasten the evaporation of the moisture. The slower the process, however, the better the sizing, as the gelatine gradually contracts and shrinks on the surface of the paper to an even skin. If the drying is hurried the gelatine cracks and does not form an impervious layer. The importance of the treatment in the drying-loft may be judged from this fact, which sometimes may be more clearly demonstrated by an analysis of the percentage of gelatine in the paper. A high proportion of animal size in a sheet should indicate superior sizing qualities and resistance to ink penetration, but it does not invariably follow that 7 per cent. of gelatine, for example, in one paper sizes it better than 6 per cent. in another. The conditions under which the latter is dried may be more favourable to good sizing qualities.

Plate-glazing.—The final process is the smoothing or polishing of the sized sheets of paper, which is effected by *plate-glazing*. The sheets of paper are placed between plates made of zinc or copper, and the pile of alternate sheets of paper and metal plates passed several times between steel rolls, which are subjected to very heavy pressure by means of compound levers and weights (Fig. 13).

The glazing imparts a high surface and finish to the paper, and at the same time reduces the bulk of the sheet by about 30–40 per cent. The tensile strength of the paper is considerably increased by judicious glazing, but the maximum strength is generally reached before the required surface is obtained. The subject of the relation of the plate-glazing process to certain physical qualities of paper would repay attention, as shown in chap. xiv.

The Manufacture of Rag Papers on the Fourdrinier Machine.

Principle.—The manufacture of paper on a machine differs essentially from the process employed for hand-made papers in that a continuous sheet or web is produced instead of single sheets. The principle of the "Fourdrinier" machine depends upon the use of a wide, endless band of wire-cloth which runs horizontally over suitable rollers. The mixture of pulp and water flows on to the wire-cloth and is carried forward, the water falling through the meshes of the wire, and the pulp settling down on the surface of the wire into the form of a wet sheet. The rationale of the process may be understood from a study of Fig. 14, reproduced from a quaint drawing which appears in Herring's book on paper-making published in 1856. Although modern machines are far more complicated than the one shown, the drawing amply illustrates the essential principles of the Fourdrinier machine.

The stock of pulp and water in the stuff-chest F, kept in a continual state of agitation by the stirrer G, flows into a narrow box M, and is distributed evenly over the surface of the endless wire W, which carries the pulp forward. The water falls through the wire, and the pulp forms a coherent sheet. The wire passes between the couch-rolls, R, and returns back to the starting-point, passing under the frame of the wet end of the machine. A guide-roll, I, serves to keep the wire in position.

Any water-marking design is produced in the paper by the dandy-roll P, which rotates on the surface of the wet sheet. The paper is transferred to a travelling felt which carries it forward to the press-rolls T, and is subjected

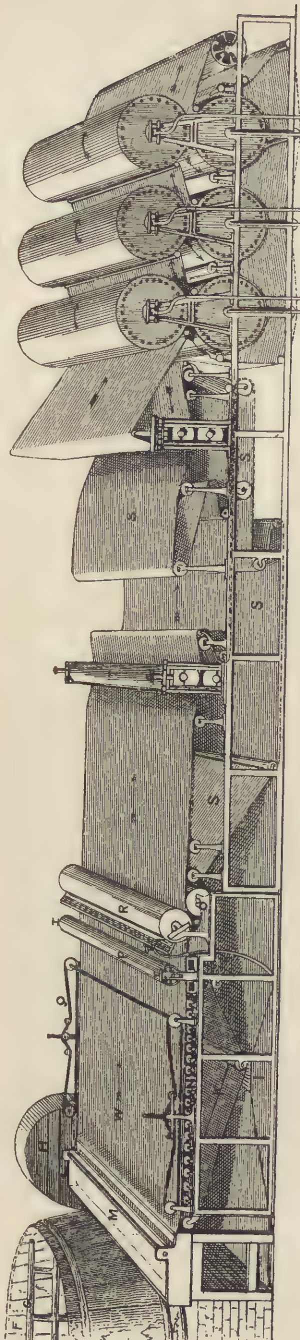


Fig. 14.—Paper-making Machine (From Herring's *Paper Making*, 1856).

to considerable pressure which removes further quantities of water. The paper is then firm enough to be dried, a process effected by means of drying cylinders, a few of which are shown.

The actual details of the conversion of the beaten pulp into a sheet of paper can only be described very briefly.

Stuff-chests.—The pulp from the beaters is discharged into a stuff-chest and a considerable quantity of water added in order to produce a mixture having a proper working consistency. Usually each machine is provided with two stuff-chests, so that while one is being filled from the beaters, the other is utilised for supplying the machine. In this way the danger of producing variations in the weight and substance of the paper is avoided. The mixture of pulp is kept in a state of gentle motion in the stuff-chest by means of slowly revolving agitators, an operation which is necessary since the pulp would otherwise gradually sink down into the bottom of the chest.

Feed-box.—The constant and regular supply of a thin diluted pulp of uniform consistency is a most important and essential feature of the process of paper-making. The machine is not fed direct from the stuff-chests, but from a small supply-box erected at a convenient height above the level of the endless wire, and in a position which the machine man can readily reach. This box is filled from the stuff-chest by means of a pump which

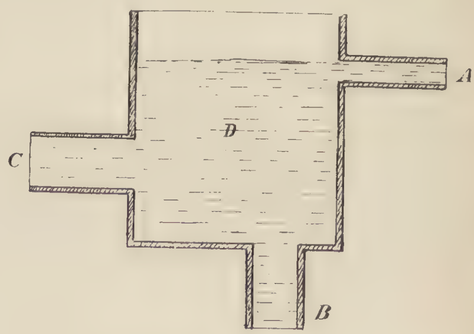


Fig. 15.—Diagram of Feed-box which regulates the Supply of Pulp to the Machine.

C. Inlet pipe, through which the pulp is pumped from the stuff-chest.
D. Supply of pulp and water in box.
B. Supply pipe to paper-machine.
A. Overflow pipe, through which surplus pulp flows back to stuff-chests.

discharges into it an amount of pulp more than the machine will take, and the surplus stuff flows away back into the stuff-chest by means of an overflow pipe fixed near the top of the box. By this means the level of the diluted mixture is kept constant, so that the rate of flow from the bottom of the supply-box through the small pipe which feeds the machine is always the same, when the tap or valve fixed to the pipe is kept open at one position.

The actual quantity of pulp discharged per minute is regulated by this valve, and the rate of flow determines the thickness and substance of the finished paper. The substance is not entirely governed, however, merely by the opening or closing of the valve, as there are other devices in use for this purpose which have to be employed according to circumstances.

Sand-traps.—The pulp flows from the feed-box direct into *sand-traps*, which keep back any dirt, impurities, or lumps of pulp. These are simply very long,

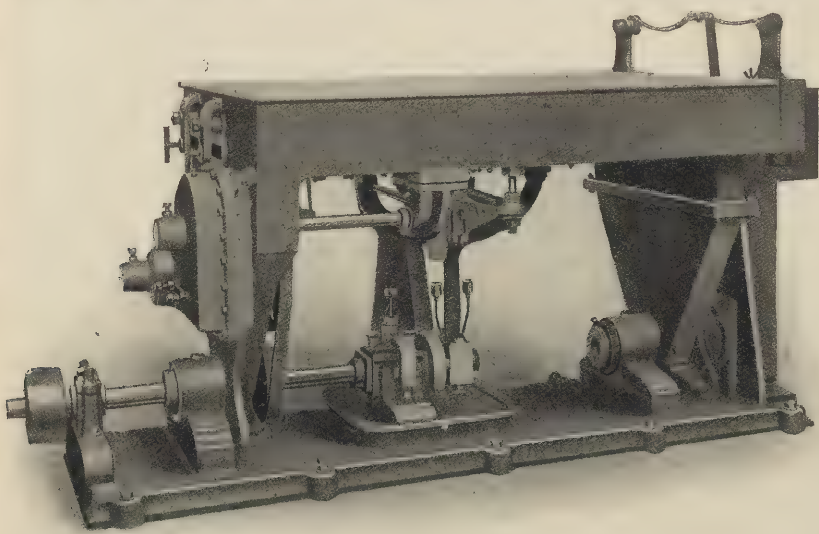


Fig. 16.—Flat Strainer for Beaten Pulp.

shallow, open boxes about nine to twelve inches wide, six to eight inches deep, and of varying length. For papers of extra good quality the sand-traps exceed 100 feet in length, consisting of narrow boxes placed side by side, connected at the ends by semi-circular channels, so that the pulp flows through the entire distance. A very slow rate of flow is required to ensure a complete separation of undesirable impurities.

At the point where the pulp enters the sand-traps, it is still further diluted with *backwater*, as it is called, which is the surplus water falling through the endless wire-cloth of the machine. This water contains a considerable quantity of fibre and other ingredients, and is thus utilised so as to prevent a serious loss of material and avoid a reduced output of paper.

The proportion of water to air-dry pulp in the mixture flowing through the sand-traps varies greatly according to the nature of the pulp, the quality of the paper being made, and other conditions of a technical character. In the case of a cheap printing paper the dilute mixture will contain about 10–12 lb. of pulp to every 100 gallons of water.

Strainers.—The pulp from the sand-traps is thoroughly strained in order to remove any dirt or lumpy pieces of fibre which have not been retained by the sand-traps.

There are many forms of machines used, but for rag pulp the so-called *flat strainer* is most frequently adopted. It consists of a rectangular iron box mounted on strong heavy supports, the bottom being formed out of a number of strong brass plates, in which are cut fine slits. These slits are very narrow, but the width varies according to the nature of the pulp, being governed by the diameter of the fibres. With fibres of small diameter the slits may be only seven-thousandths of an inch.

The rectangular box is kept in a state of rapid and violent motion while the pulp flows on to the surface of the brass plates, in order to promote the screening process. The metal of the under surface of the plates at each slit is cut away to prevent any stoppage, and the upper surface is kept clean by the continuous movement of rubber brushes passing slowly from one end of the box to the other. The clarified mixture flows away from the lower surfaces of the strainer-plates into an outlet pipe.

Fig. 17.—Section of a Strainer-plate.

Machine Wire.—The strained pulp runs into a long narrow box placed at the head of and across the full width of the paper-machine, and gradually overflows the front edge of the box, which is cut down to ensure an even flow of pulp. The transfer of the stream of pulp to the wire is effected by the *apron*, a strip of thin sheet rubber or similar material, one end of which is nailed to the box and the other left free to trail on the wire as it comes up over the first supporting roll and travels forward.

The first portion of the paper-machine, where the pulp is formed into a sheet of wet paper, is known as the *wet end* in contradistinction to the end section devoted to drying and finishing, usually designated the *dry end.*

The wire is a long endless brass wire-cloth about 40 to 50 feet in length and 70 to 90 inches wide, with a fine mesh of 60 to 70 wires per inch. It is stretched on two rolls: the *breast-roll*, situated near the narrow box containing the pulp, and the *under couch-roll.* The wire travels from the breast-roll over a large number of *tube-rolls*, or hollow brass cylinders three inches in diameter, placed very close together on a rectangular frame and then underneath the couch-roll, after which it is carried back below the frame by means of the *under couch-roll*, and sundry other rolls of small diameter which serve to keep the wire tight.

Deckle-straps.—The pulp flows from the strainers over the apron on to the travelling machine-wire, and then immediately underneath the *slice*, a flat brass bar placed on edge, which is adjustable both as to its width and height above the wire-cloth. The distance of the slice from the wire determines the thickness of the pulp flowing on to the wire and, therefore, the substance and weight of the paper, to some extent, but the actual thickness of the paper is controlled by other conditions to a greater extent, as will be seen by reference to the finishing operations.

In order to prevent the pulp spreading too much and flowing over the wire at each side *deckle-straps* are used. These consist of thick, heavy, endless bands of rubber, of square section, which are carried on grooved brass pulleys and which travel along the machine-wire at each side and in close contact with it.

The apron at one end of the wire, the couch-roll at the other end, with the deckle-straps on each side, all combine to form in effect an endless *deckle*, while the machine-wire forms the endless *mould.* The intermittent *hand* process is thus converted into a continuous machine process.

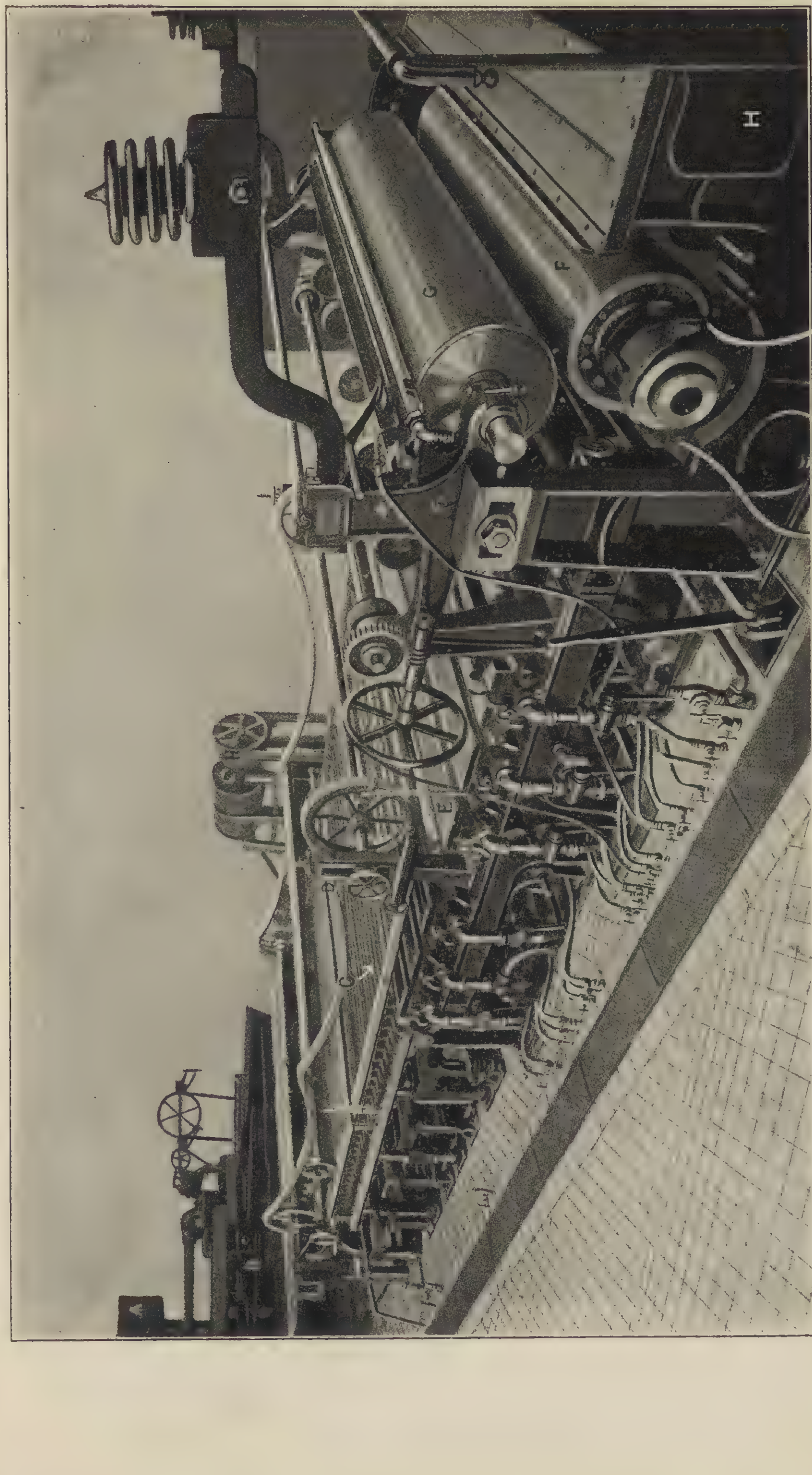


Fig. 18.—Wet End of a Paper-machine.

A. Feed box containing pulp and water. B. Strainers. C. Machine wire.
D. Deckle-strap. E. Suction-boxes. F, G. Couch-rolls. H. Press-rolls.

Vacuum-boxes.—Directly the pulp flows under the slices, the water begins to fall through the wire. The rapid flow of the mixture on to the wire causes all the fibres to assume a position parallel to the sides of the wire, and pointing in the direction towards which they are travelling. But this tendency has to be counteracted, for a paper made up of fibres pointing almost exclusively in one direction is generally of inferior strength. The imitation of the *shake* given by the vatman in producing hand-made sheets is accomplished on the paper-machine by a shaking motion imparted to the rectangular frame carrying the breast-roll, tube-rolls, and wire. This shake causes many of the fibres to assume a position at right angles to the *machine direction*, so called, and tends to equalise

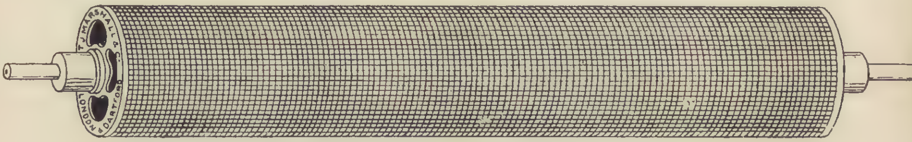


Fig. 19.—A "Wove" Dandy-roll.

the strength of the sheet of paper in the two directions. The fact, however, that the water begins to leave the pulp immediately after passing the slices prevents the fibres on the under surface of the flowing sheet of wet paper from *felting* properly, because there is not sufficient time for them to be affected by the shake. The fibres in the water just above are much more sensitive to the action of the shake and *felt* much better. This curious difference in behaviour can easily be seen by comparing the two sides of a sheet of mottled paper.

The draining of the water from the pulp is hastened by the tube-rolls which draw the water away from the wire very rapidly by capillarity, though the main purpose of the tube-rolls is to support and keep the wire in its proper horizontal position. The further removal of water is produced by a number of *vacuum-boxes*, usually two or three, placed close up underneath the wire just in front of

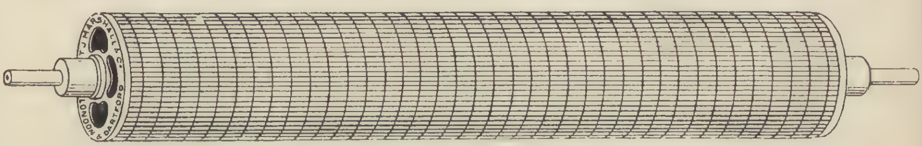


Fig. 20.—A "Laid" Dandy-roll.

the couch-roll. The suction, induced by special powerful pumps, draws a large quantity of water from the wet sheet of pulp as it travels continuously over the vacuum-boxes.

Save-all.—The very large quantity of water escaping through the meshes of the wire is not allowed to run away, but is carefully caught in a large shallow box or *save-all*, placed under the wire close up to the tube-rolls. It contains a large amount of fibre, varying from 5 to 15 lb. of air-dry fibre per 1000 gallons, and this cannot be ignored. It is pumped up and used for diluting the pulp from the stuff-chests before it flows into the sand-traps. Any surplus over and above the amount required for this is utilised in the beating-engines.

Dandy-roll.—Before the pulp has travelled over all the suction-boxes it is usually submitted to the action of the *dandy-roll*, which carried on suitable

bearings fixed to the frame supporting the tube-rolls and wire, revolves on the surface of the wet sheet and presses it.

The dandy-roll is a light skeleton drum, the surface of which is wire gauze. If the wire gauze is exactly the same pattern as the wire on the machine, consisting of fine wires interwoven in the usual way, the paper does not show any distinctive wire-marks when held up to the light and examined, or at most it may only show minute diamond-shaped markings. A wire and dandy-roll of this description produces *wove* paper.

If the dandy-roll is built up of a large number of fine straight wires running parallel to the axis of the roll and forming the cylindrical surface, intersected by cross wires bound round the drum at right angles to the axis and at even distances apart, then the impressions produced on the paper are those peculiar to what is known as *laid* paper, that is, a number of lines very close together intersected by lines at right angles about one inch apart.

If raised wires are sewn or soldered to the wire cylindrical surface of either the *wove* or *laid* type, forming a pattern, then the impressions caused by the raised wires produce a thinning of the pulp just where the raised pattern comes into contact with the wet sheet, and this results in the formation of the *water-mark*.

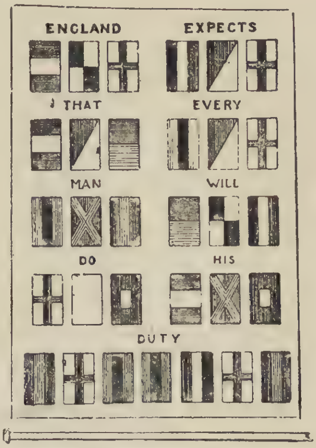


Fig. 21.—Photograph of a recent Water-mark Design.

Couch-rolls.—The wet sheet of paper on leaving the vacuum-boxes is carried by the wire between the two *couch-rolls*, the upper one being a wooden or iron cylinder covered with a felt jacket. The pressure of the top couch-roll causes the fibres to adhere together and "felt" more completely, and at the same time removes further quantities of water. The wire passes round the lower couch-roll and back under the machine to the breast-roll, but the wet sheet is picked off by the machine-tender from the surface of the wire by a peculiar movement, which cannot be easily described, and transferred to an endless felt, which carries the sheet forward between heavy iron rolls.

Press-rolls.—The function of the heavy iron drums known as press-rolls is to render the sheet more compact and adherent. Usually the paper-machine is provided with two sets of press-rolls, known as the *first press* and *second press* and the use of two sets ensures a smooth paper with both sides practically alike in texture and finish. If only one set of press-rolls is employed, then the marks of the felt are more readily detected on one side of the paper.

Drying-cylinders.—The wet sheet of paper leaving the press-rolls contains about 70 per cent. of moisture, and this excess of moisture is removed by means of the *drying-cylinders* on the paper-machine. These are large hollow cast-iron cylinders, twelve or fifteen in number, each three to four feet in diameter, heated internally by the exhaust steam from the engine which drives the machine.

The paper is led over the several drying-cylinders, being carried from one to another by travelling felts, which press the paper against the heated surface of each cylinder, the water evaporating gradually as the paper travels towards the last cylinder. Great care is exercised to prevent hasty drying, since the behaviour of the paper when finished is largely influenced by the method of drying, and the defects known as cockling, wavy edges, creases, &c., are frequently traceable to neglect of the proper conditions of drying.

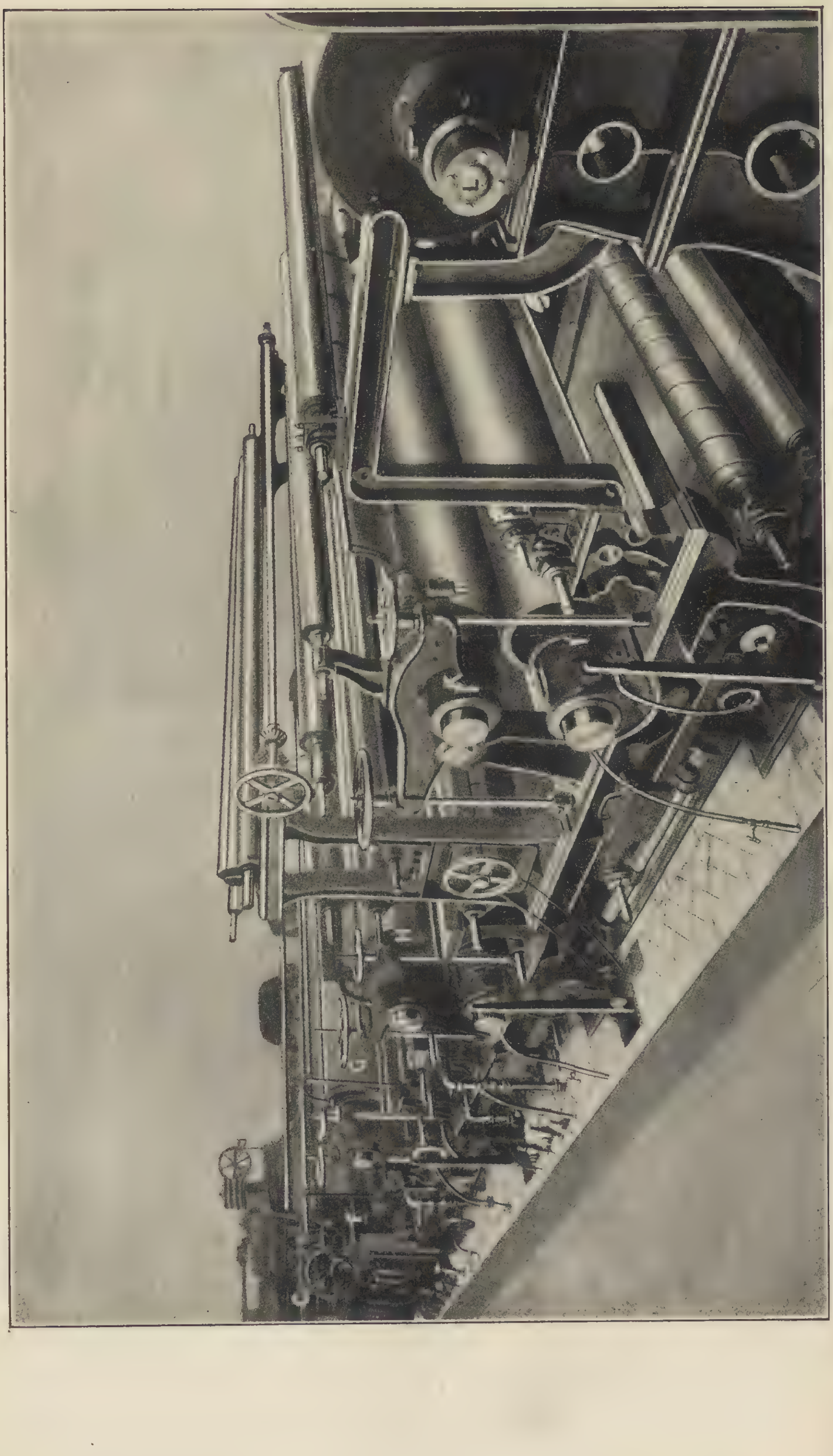
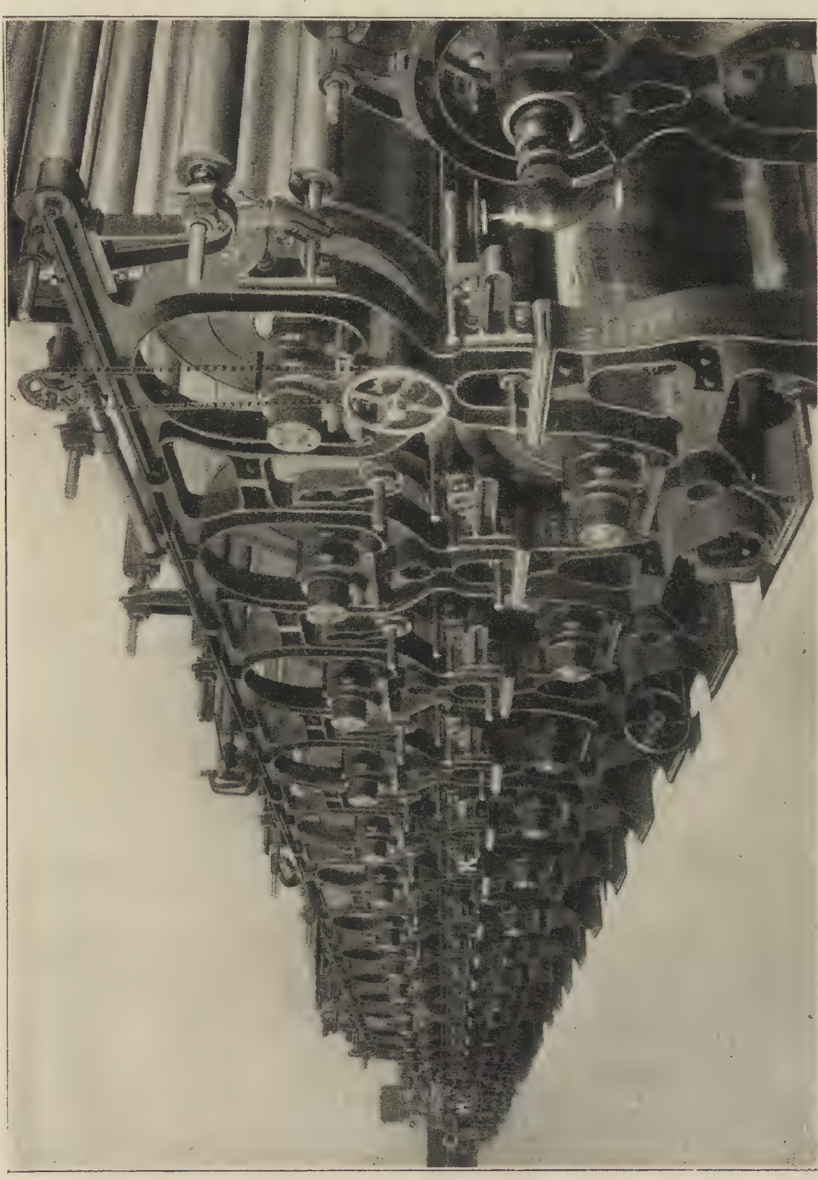


Fig. 22.—Wet Presses of a Paper-machine.

C. Wire end of the machine. G. First press-rolls. K. Third press-rolls.

E. Couch-rolls. H. Second press-rolls. L. First drying cylinder.

Calenders.—The nature of the operation through which the paper passes after being dried depends on the class and quality of paper.



C H K L K

Fig. 23.—Drying-cylinders of a Paper-machine.

C. Wet end of machine.
H. Press-rolls.
K. Drying-cylinders (usually 15 on a machine intended for rag papers, and 28 or 32 on a news machine).

With the highest grades of paper, the dry sheet is wound up into a reel direct from the drying-cylinders in order that the paper may be tub-sized before being calendered. With a medium quality of paper the operation of sizing is effected on the paper-machine by special additional apparatus, so that the dried paper can be polished or calendered by one or more stacks of *calender-rolls* placed at the end of the machine, following the drying-cylinders. (Fig. 60.)

In cases where the paper has been sufficiently sized, either with rosin size in

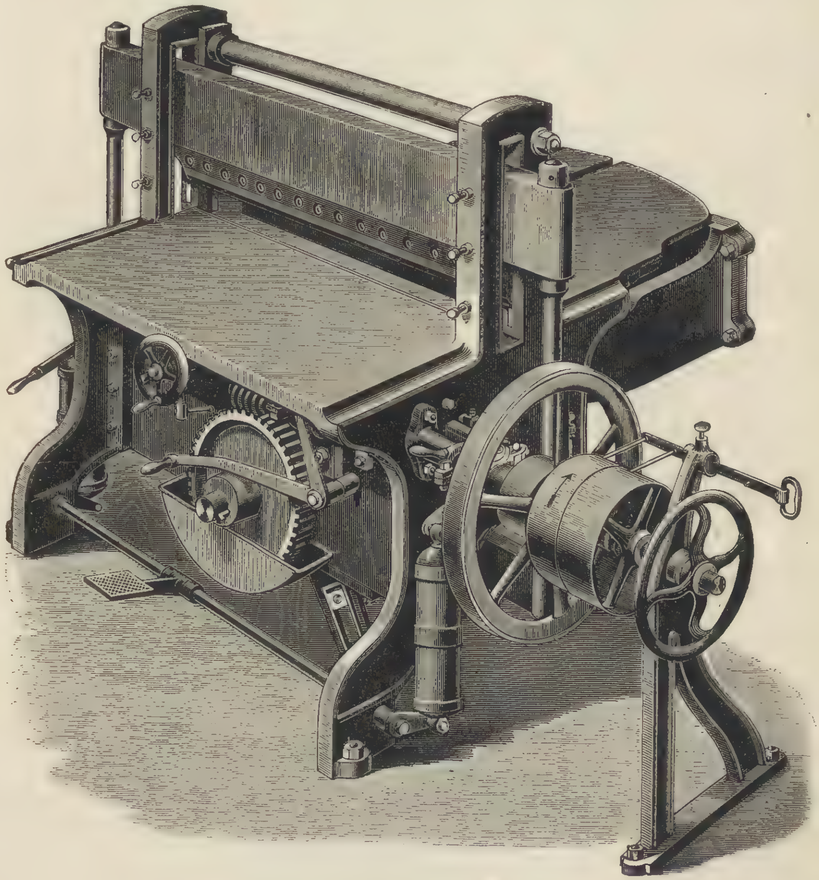


Fig. 24.—Self-clamping Guillotine.

the beater or with gelatine on the paper-machine, the operation of calendering or polishing can be completed by the machine calenders, but when necessary a further finish can be given to the paper by means of supercalenders. (Fig. 31.)

Cutting.—The reels of paper after being calendered are then cut into sheets of the required size by means of a reel paper-cutter. (Fig. 33.)

For still further reducing the size of cut sheets, or for cutting spoilt sheets of paper into smaller sizes which can be made use of, a *guillotine* paper-cutter is employed. A pile of sheets is laid upon the table of the machine and a strong

steel knife lowered downwards, shearing the pile into two portions. The piles are turned round, and cut again until the operation is completed.

Sorting.—The cut sheets are carefully examined by girls, who throw out any dirty, spotted, or defective sheets. The latter are sometimes packed up and sold under various names such as seconds, thirds, outsides, or *retree*, terms applied to paper not good enough to pass muster as first quality. The good paper is counted up into reams of 480 or 500 sheets.

Packing.—The reams of paper are tied up in wrapping paper and put into stock. When required for export, the reams are carefully stacked into bundles of 3 to 4 cwt., compressed by powerful hydraulic presses, and suitably fastened up with wooden battens and iron bands.

CHAPTER IV

ESPARTO. STRAW. NOTES ON BEATING

Esparto—Sorting, cleaning and boiling—Bleaching, beating, loading, sizing—Manufacture of rosin size—Colouring—Making paper on the Fourdrinier machine—**Straw**—Preparation of straw pulp—Washing, bleaching, &c.—**Beating**

The Preparation of Esparto Pulp.

Cleaning.—Esparto grass reaches the paper-mill in the form of huge bales containing the grass bundles tightly packed together by hydraulic pressure. These bales are opened and the bundles of esparto loosened by women. The material is then carefully sorted and thoroughly cleaned either by hand or machinery. Usually the loosened grass is passed through a "willow," or duster, similar to that employed for rags, which beats out all dust, dirt, small stones and sand, and discharges the grass upon a travelling band, so that the coarse root-ends, weeds, and extraneous matter can be readily picked out if necessary.

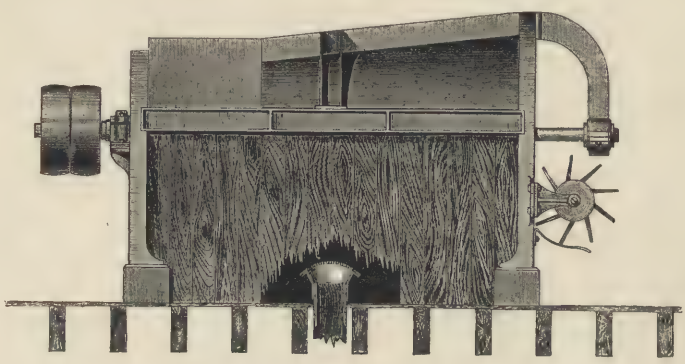


Fig. 25.—Esparto and Straw Duster.

The cleaned grass is carried from the willowing machine to any desired height by means of travelling bands, and thus furnished to the digesters.

Boiling.—In a well-arranged paper-mill the boilers are erected in convenient positions so that they can be quickly filled with the grass. The type of digester now almost exclusively used for esparto grass is known as Sinclair's Vomiting Boiler. It is a stationary cylindrical digester capable of holding two to three tons of grass, provided with a man-hole at the top, through which the fibre is furnished from the floor above, and a second man-hole fitted to one side of the boiler near the bottom, through which the boiled grass may be emptied out.

Steam is admitted through a pipe at the bottom of the boiler, and this causes a continuous circulation of the caustic soda liquor upwards through "vomit" pipes, fitted to the opposite sides of the apparatus, and over a perforated plate

fixed in the upper part of the boiler, the liquor then falling back upon the grass. The digester is also provided with suitable inlet pipes for caustic soda liquor, and for clean water, and outlet pipes for blowing off the steam and for the discharge of the spent liquor.

The boiler is first supplied with the proper quantity of caustic soda liquor, and the steam turned on in order that the grass may be quickly saturated, for by this means a much larger quantity of grass can be filled in. The upper man-hole is bolted down, and the full working pressure of steam admitted. The period occupied in boiling depends on the strength of the liquor and the pressure of steam. A boiling usually occupies four to five hours, the steam pressure being 40 to 50 lbs. per square inch, the proportion of caustic soda 14 to 16 per cent. on the weight of grass.

When the boiling is completed the caustic liquid, now perfectly black from the presence of the non-cellulose constituents of the esparto removed by the operation, is discharged into store-tanks. The boiled pulp is carefully washed under a system which ensures a thorough cleansing of the fibre with the least possible quantity of water, because the washings are not thrown away as in the case of rags, but are run down into the "black liquor" store-tanks to be subsequently dealt with.

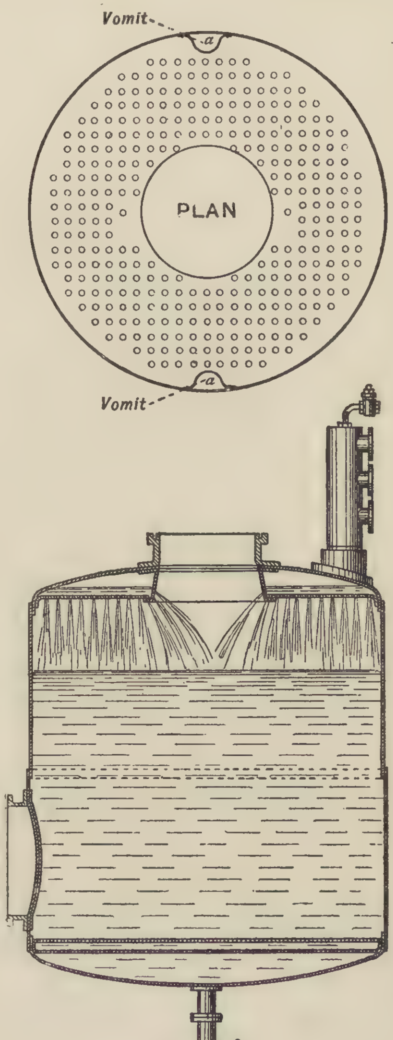


Fig. 26.—Plan and Section of Sinclair Vomiting Esparto Boiler.

Soda Recovery. — These black liquors contain all the caustic soda originally used, together with organic matter removed from the esparto grass, the latter amounting to about 50 per cent. of the weight of grass treated. The liquors are boiled down and concentrated to a small bulk by suitable appliances, generally some form of vacuum evaporating machinery, and this gives a thick syrupy liquid, which readily burns when run on to a hearth and brought into contact with a fire. By this means the organic matter is burnt off, and the mass left behind consists mainly of impure carbonate of soda. This residue is known as "recovered ash," and when boiled in suitable tanks with lime is reconverted into caustic soda, which can be utilised over again. About 75 to 85 per cent. of the soda used in the treatment of esparto can be recovered.

Washing.—The fibre, washed by a more or less elaborate system for the

removal of the black liquor, is nearly always submitted to a final washing in the breaking-engine to remove the last traces of dirty water, the operation reducing the grass at the same time to the condition of pulp.

Bleaching.—The bleaching of esparto pulp is accomplished by methods which have been found suitable for rags, such as the system of steeping in tanks, or circulating the pulp and bleach liquor in the breaker. Of recent years, esparto has been bleached in tall cylindrical vessels, the mixture of pulp and bleach

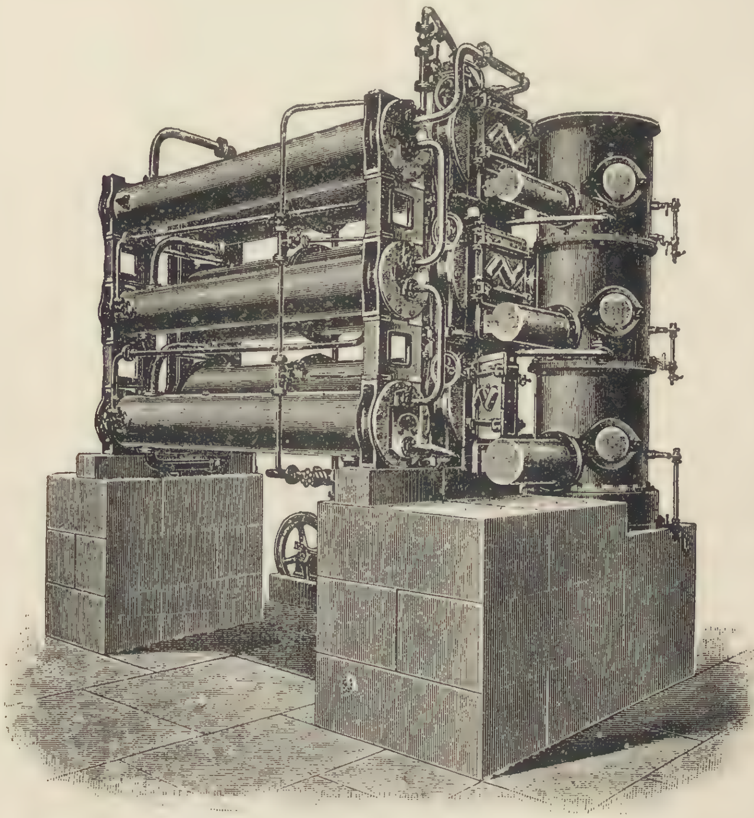


Fig. 27.—Yaryan Multiple-effect Evaporating Plant for the Treatment of Esparto Liquors.

being kept in constant circulation by a centrifugal pump which discharges the stuff from the bottom of the vessel through a pipe into the open top, where the pulp falls on a disc of wood and spreads over the surface of the mixture, coming freely into contact with the air, a method said to be economical in the use of bleach, but which is probably wasteful in the matter of power. (*See* Fig. 54.)

Presse-pâte.—The bleached pulp is then thoroughly washed to remove every trace of bleach residues, and worked up into moist sheets of pulp on a *presse-pâte.*

The presse-pâte closely resembles the *wet end* of a paper-machine, and it is used for converting bleached pulp into sheets for convenience in handling and transport. The pulp mixed with a large quantity of water flows through a series of shallow open boxes, or *sand-traps*, provided with wooden baffle-plates which serve

to retain dirt and coarse root-ends incompletely digested, and then on to strainers. The purer fibre passes on to a moving endless wire-cloth, about thirty feet long and sixty or seventy inches wide. The wire-cloth is supported in a horizontal position on brass rolls, and the continuous rotation of the rolls causes the wire to travel between the sand-traps and the *couch-roll*, carrying on its upper surface the mixture of wet pulp. As the pulp flows on the wire and is carried forward, the water falls through the meshes of the cloth, leaving a coherent mass of pulp on the wire. Further quantities of water are drawn from the pulp by means of *vacuum-boxes* placed immediately under the surface of the wire, and finally, the pulp passes under the heavy couch-roll, which squeezes more water out. The sheet of wet pulp is led carefully on to an iron spindle, and a continuous roll of pulp is produced which consists of esparto half-stuff.

In some cases the presse-pâte is dispensed with, and the bleached pulp after washing is run down into draining-tanks, to be afterwards dug out with shovels into trucks as required.

Beating. — The beating of esparto pulp for the production of pure esparto papers is quite different to the treatment necessary in the manufacture of strong rag papers. The individual fibres possess peculiarities of structure compelling the paper-maker to adopt a method of beating which will bring out qualities looked for in esparto paper. The differences in the appearance and feel of esparto papers cannot be varied to such an extent as with fibres like rag and wood, but on the one hand it is possible to make a soft bulky *antique*, and on the other a fairly strong *supercalendered writing* out of esparto pulp. The main factor in producing this difference is the method of beating.

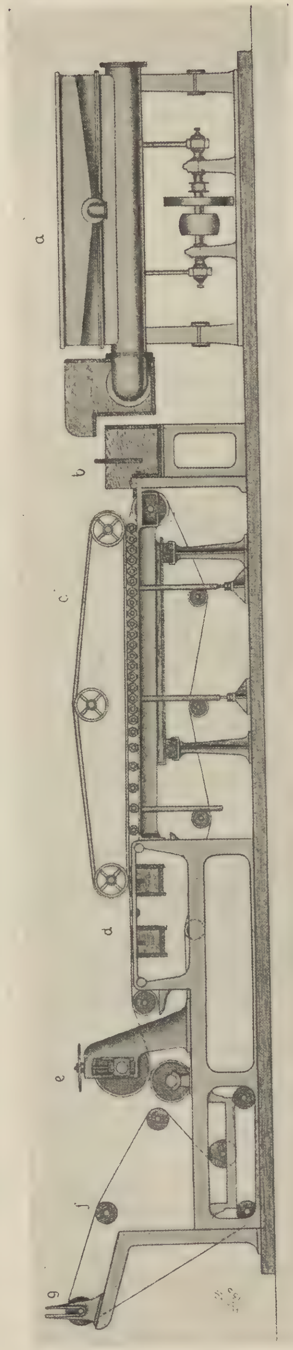


Fig. 28.—Presse-pâte for Esparto Pulp.

a. Strainers.
b. Feed-box.
c. Wire with deckle-straps.
d. Suction-boxes.
e. Couch-rolls.
f. Carrying felt.
g. Roll of esparto pulp finished.

Esparto half-stuff can be beaten in the "Hollander," a machine which has been described in chap. iii. It is, however, usual to employ the Umpherston beater, or some of the more modern types of beaters, in which the circulation of the pulp is not maintained by the beater-roll, but by some independent contrivance.

The Umpherston beater is similar in principle to the old "Hollander," in that the engine is divided into two channels, but the second channel is underneath the first, so that the pulp is discharged by the beater-roll over the *backfall* into the second channel, and circulates underneath the backfall, returning to the front of the beater roll ready for continued treatment.

In the production of soft bulky esparto papers the stuff is put into the beater

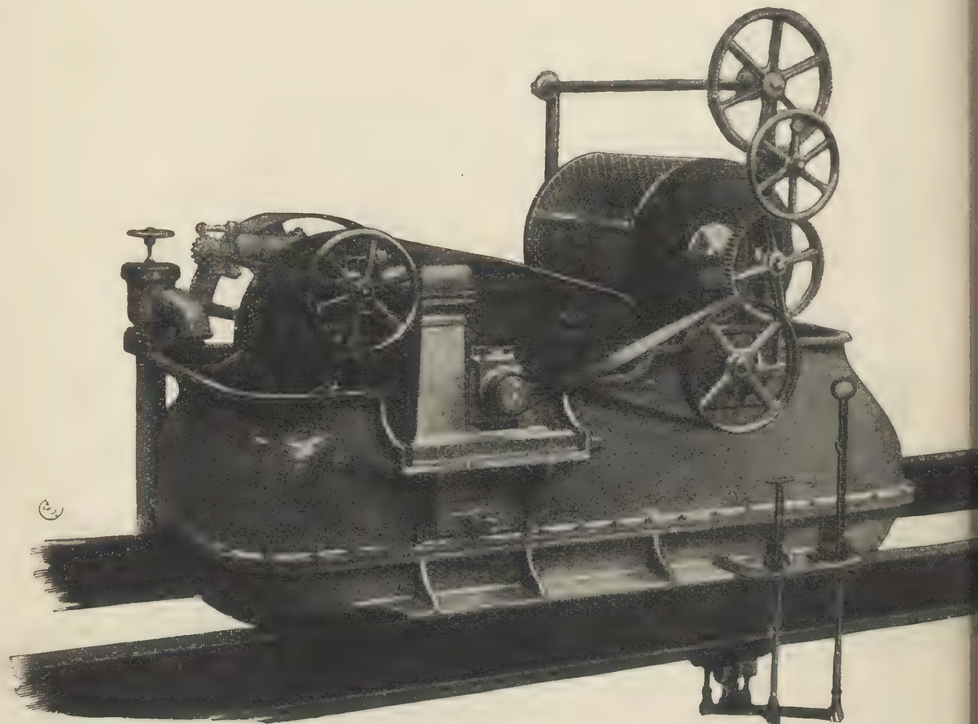


Fig. 29.—Umpherston Beater.

and beaten for a short period, varying from an hour to an hour and a half, the object being to reduce the pulp to a suitable length and condition without allowing the water to assimilate with the fibres, since prolonged beating causes the pulp to work "wet," as fully explained in chap. iii., which is undesirable in pulps intended for bulky light papers.

In the production of the stronger, more closely made writing papers, the esparto is beaten for two to four hours according to requirements, the result being a harder sheet.

Loading.—During the actual process of beating, certain more strictly chemical operations are carried out. If a mineral filling is required, it is added to the pulp soon after the beating has commenced, to ensure thorough incorporation. China-clay is the mineral most frequently added, and this is used either

in the form of the dry powder, or in the form of a thin creamy paste, made by stirring the powder with water in tanks provided with agitators.

Engine-sizing.—The sizing of the paper is also carried out in the beater, rosin size being used. The fact that the pulp is sized in the beater explains the use of the term E.S. as applied to various papers, the letters standing for the words "Engine sized."

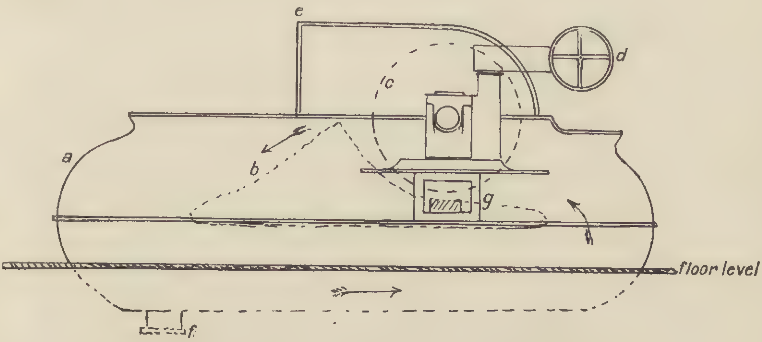


Fig. 30.—Section of Umpherston Beating-engine.

a. Vessel containing pulp.
b. Backfall.
c. Beater-roll.
d. Regulating wheel for roll.
e. Beater-roll cover.
f. Outlet-pipe.
g. Bed-plate of stationary knives.

Sizing.—The necessary amount of rosin soap, prepared as shown below, is added to the mixture of pulp and loading soon after the latter is incorporated. The soap dissolves in the water to a thin milky solution and mixes with the pulp, but does not size the fibres. The sizing is only complete when the rosin and rosin compounds are actually precipitated upon the fibres and thrown out of solution, a change which is brought about by the addition of alum to the contents of the beating-engine. The alum reacts with the soap, which consists of free rosin dissolved in resinate of soda, forming an insoluble resinate of alumina and insoluble free rosin, and these substances being in an exceedingly fine state of divison become evenly distributed through the whole mass of pulp.

It may be noted that the mere addition of rosin soap to the pulp in the beating-engine does not in itself size the paper, the process being carried out as follows:

The proper quantities of pulp and loading, if any, are put into the beater. The requisite amount of rosin soap drawn off from the store-tanks in pails is added after a short time and thoroughly incorporated by the circulation of the stuff in the engine.

A solution of alum is then poured into the beater to complete the operation, the function of the alum being to precipitate the rosin upon the fibres so as to ensure a maximum sizing effect. The nature of the change brought about by the alum may be demonstrated by pouring a small quantity of a dilute solution of alum into some rosin soap, when the milky liquid gradually becomes clear and a curdy deposit is formed, which is a mixture of free rosin and resinate of alumina thrown out by the alum. This reaction takes place in the beater, and the resinous deposit is distributed through the mass of pulp. The completion of the process does not actually take place until the paper has passed the drying-cylinders, the heat of which possibly spreads or melts the minute globules of resinous matter attached to the individual fibres.

Rosin Size.—This size, which is so largely employed for common writing papers and all printing papers is made from rosin and soda ash.

Rosin, or colophony, is a brownish-coloured residue obtained during the distillation of crude turps. The turpentine exudes from certain firs and pines, and is distilled in order to separate the pure spirits of turpentine from the heavier resinous substances which are known collectively as colophony. Its colour ranges from yellow to very dark red, and the commercial product is frequently dirty, being contaminated with splinters of wood, straw and foreign impurities, which have to be carefully removed at the paper-mill.

The substances present in rosin are composed mainly of organic acids known as pinic and sylvic acids, which are insoluble in water. They are capable of reacting with alkaline substances, such as caustic soda and carbonate of soda, to form bodies soluble in water just as acids like sulphuric and hydrochloric react with alkaline substances to form salts. The salts formed in the case of rosin are called *resinates;* they are soluble in water and give a so-called *rosin soap.*

The soap is made by boiling a stated quantity of well-powdered rosin in a steam-jacketed pan for four to six hours with carbonate of soda. The alkali is put into the pan with the requisite quantity of water and boiled. The rosin is added gradually and cautiously, so as to avoid any risk of the stuff boiling over, since the mixture froths up vigorously owing to the liberation of carbonic acid.

The proportions of soda and rosin vary in different paper-mills according to requirements. If 100 lbs. of rosin are boiled with 17 lbs. of soda, the soap formed is a viscous brown transparent solution which, mixed with water and diluted, is quite clear. The rosin combines with the alkali to produce a neutral resinate of soda usually designated *brown size.*

Now the resinate of soda has the property of dissolving rosin. Hence the proportion of rosin may be considerably increased, but the *acid size* formed does not give a clear solution with water, but a milky liquid which is known as *white size.* If 100 lbs. of rosin are boiled with 13 lbs. of soda, an acid size, so called from the presence of an excess of rosin in the shape of rosin acids, is produced. When diluted with water, the free rosin is reprecipitated in the form of exceedingly fine globules distributed as an emulsion in the water.

A rosin soap containing a very large percentage of free rosin varying from 30 to 40 per cent. may be obtained by boiling the necessary materials under pressure in a closed vessel. The use of such a rosin size has been resorted to because it is supposed to give the best results, but on this point there is a considerable difference of opinion.

TABLE IV.

Analysis of an Acid Size, containing a small proportion of Free Rosin.

Combined Rosin	40·0	per cent.
Free Rosin	15·0	,,
Total Soda	8·0	,,
Water	37·0	,,
	100·0	,,

Analysis of an Acid Size containing a large proportion of Free Rosin.

Combined Rosin	35·5	per cent.
Free Rosin	24·0	,,
Total Soda	3·5	,,
Water	37·0	,,
	100·0	,,

Colouring.—The colouring of esparto paper is usually limited to a mere toning of the natural colour of the pulp by means of a very small proportion of some aniline dye in order to produce the required shade of white. The dye is prepared

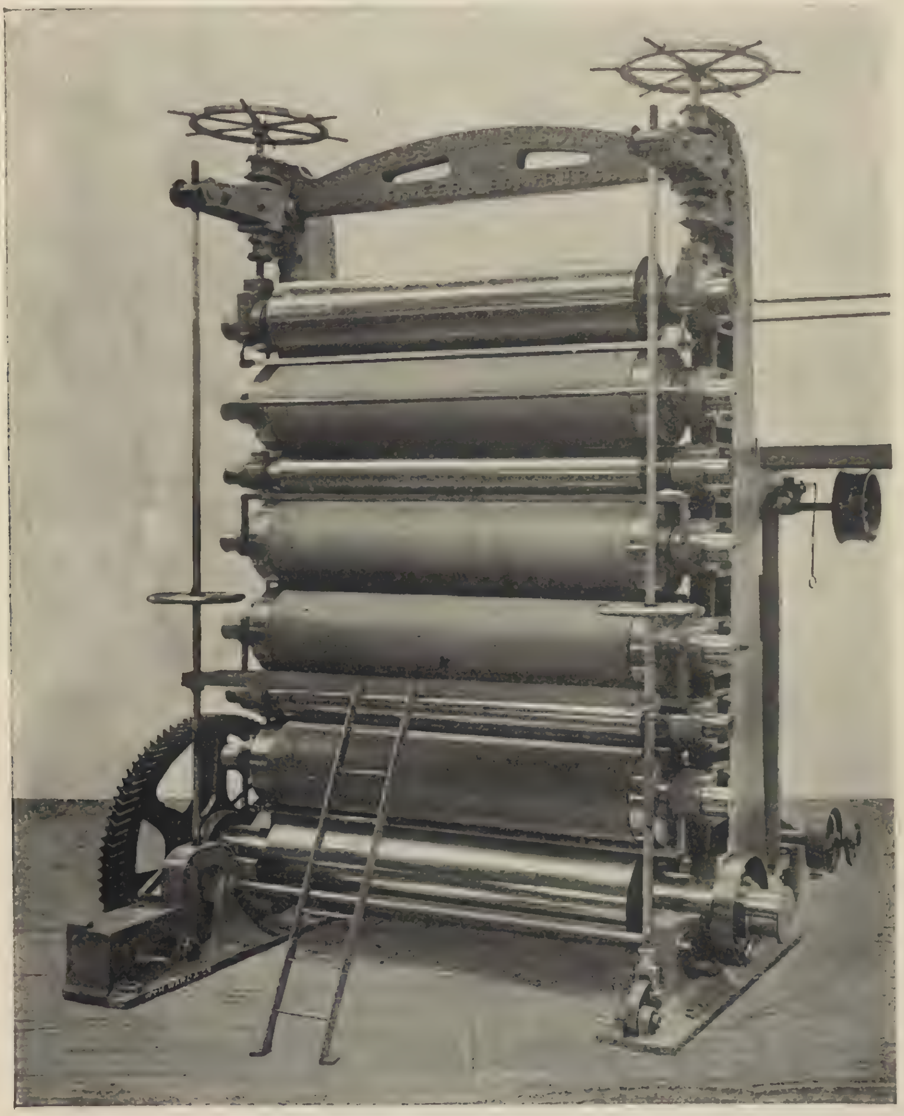


Fig. 31.—Supercalender.

by dissolving a known weight of the solid colouring-matter in a given volume of water, an aliquot portion of the mixture being added to the beaten pulp.

Making the Paper on the Fourdrinier Machine.—The pulp when properly beaten is discharged into the *stuff-chests* of the machine, and converted

into paper by the methods described in chap. iii., which it is unnecessary to repeat here.

There are many essential and important details in the actual manipulation of the machine which cannot be dealt with except in a larger treatise devoted to the subject of manufacture, and, moreover, an adequate appreciation of these details is only possible by a paper-maker familiar with the working of a machine.

The paper is pressed on the press-rolls, dried on the cylinders, and partially calendered before it is reeled up.

Finishing.—Esparto paper intended for writings is usually finished on the *supercalenders.* The partially machine-calendered paper is removed in reels from the end of the Fourdrinier machine, taken to the finishing-room, and supercalendered.

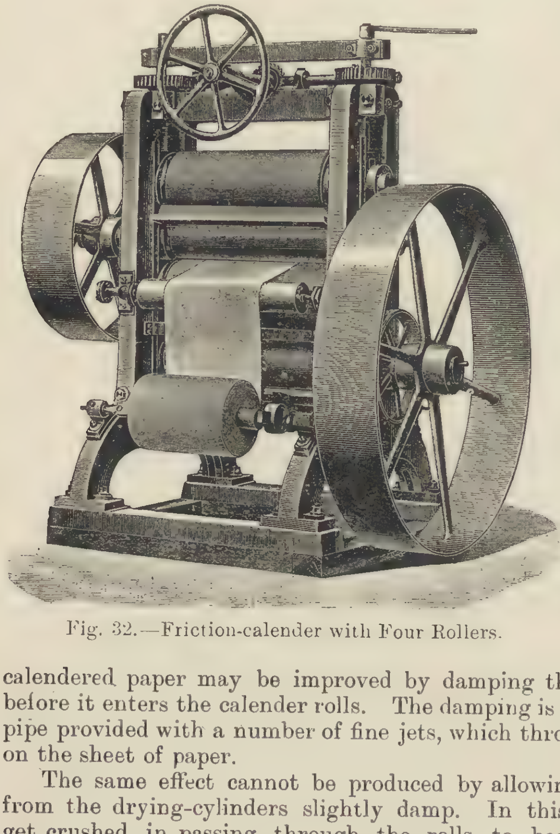


Fig. 32.—Friction-calender with Four Rollers.

The *supercalender* consists of a number of rolls, alternately chilled iron or steel rolls, and *paper bowls.* The bottom roll of the stack is a heavy roll of large diameter, capable of bearing the entire weight of all the rolls in the stack. Every alternate roll is made of paper tightly compressed by hydraulic pressure on an iron spindle, the surface being turned up in a lathe perfectly true and then polished. (Fig. 31.)

As the paper passes through the stack of rolls, being in contact with the polished surfaces of metal and paper, it becomes very smooth and highly glazed.

The surface of a supercalendered paper may be improved by damping the surface of the sheet just before it enters the calender rolls. The damping is effected by means of a steam pipe provided with a number of fine jets, which throw a thin spray of wet steam on the sheet of paper.

The same effect cannot be produced by allowing the paper to come away from the drying-cylinders slightly damp. In this case, the paper is apt to get crushed in passing through the rolls, to become transparent, and considerably reduced in bulk. A little water on the surface of a dried sheet affects only the surface and not the whole bulk of the paper, so that the result of the moisture is confined to an improvement of surface.

Friction glazing.—A still higher finish can be given to all kinds of paper by the *friction-glazing* rolls, which are similar in general construction to the supercalender, but differ in having large paper bowls, or rolls, and small metal ones. The latter revolve at a higher speed than the former, and the paper is submitted to considerable friction. A small quantity of beeswax on the iron rolls imparts a final polish to the sheet.

Cutting.—The reels of supercalendered paper are finally cut up into sheets on a cutter. Six or eight reels are mounted on suitable shafts (a, Fig. 33) at one end of the cutter, and the paper from all the reels led together over an inclined

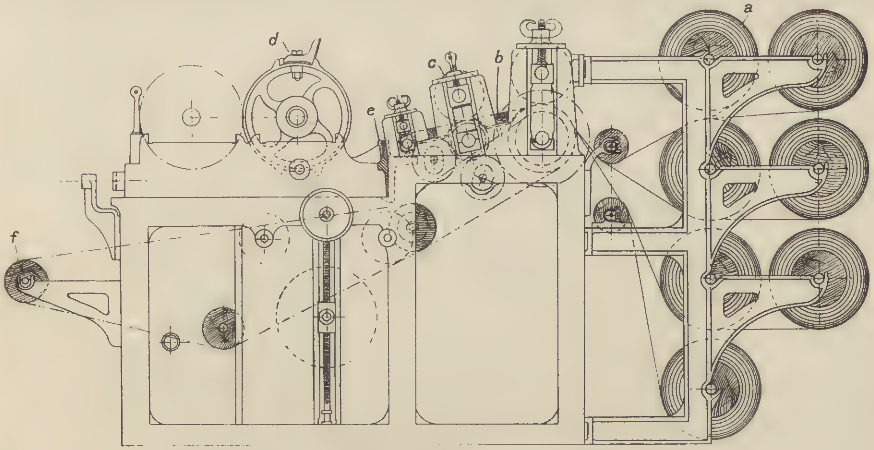


Fig. 33.—Paper-cutter.

table (b), slit first into required widths by revolving circular knives (c), and into the required lengths by a knife which cuts the sheet at right angles (d). The slit paper passes over the edge of the inclined table, this edge being a fixed stationary steel knife (e), and at regular intervals a heavy steel blade (d) fastened to a revolving drum comes into contact with the stationary knife and shears off the paper into proper lengths. The knives are all adjustable, so that the paper can be cut to any given size The cut sheets drop on to a travelling felt (f).

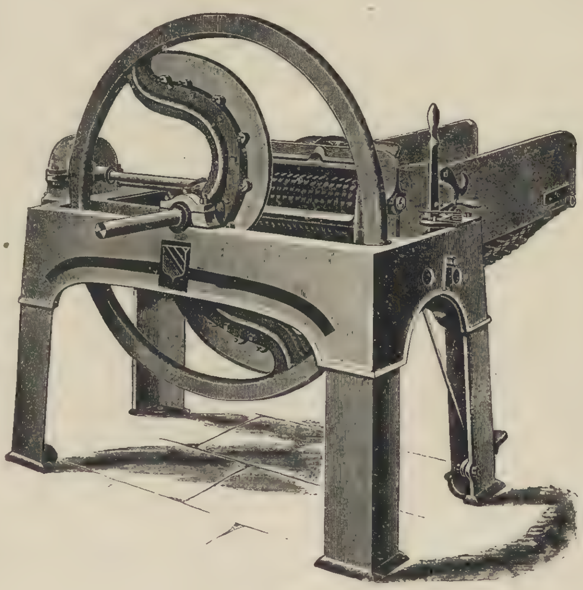


Fig. 34.—Straw-chopper.

Straw Cellulose.

A fibre resembling esparto in chemical composition, but possessing physical qualities of a different order, is straw. The treatment by which the raw material is converted into straw cellulose is identical with that used for esparto, and the process may be fitly described at this point.

The Preparation of Straw Pulp.—The process in use for the manufacture of a bleached straw pulp suitable for blending with other fibres to give a fairly

hard paper is very similar to that employed with esparto, but the conditions of boiling are more severe on account of the presence of compound celluloses in straw, which require to be treated differently to those found in esparto.

Barley, oat, wheat and rye straws all yield good pulps, which differ slightly in quality and working properties.

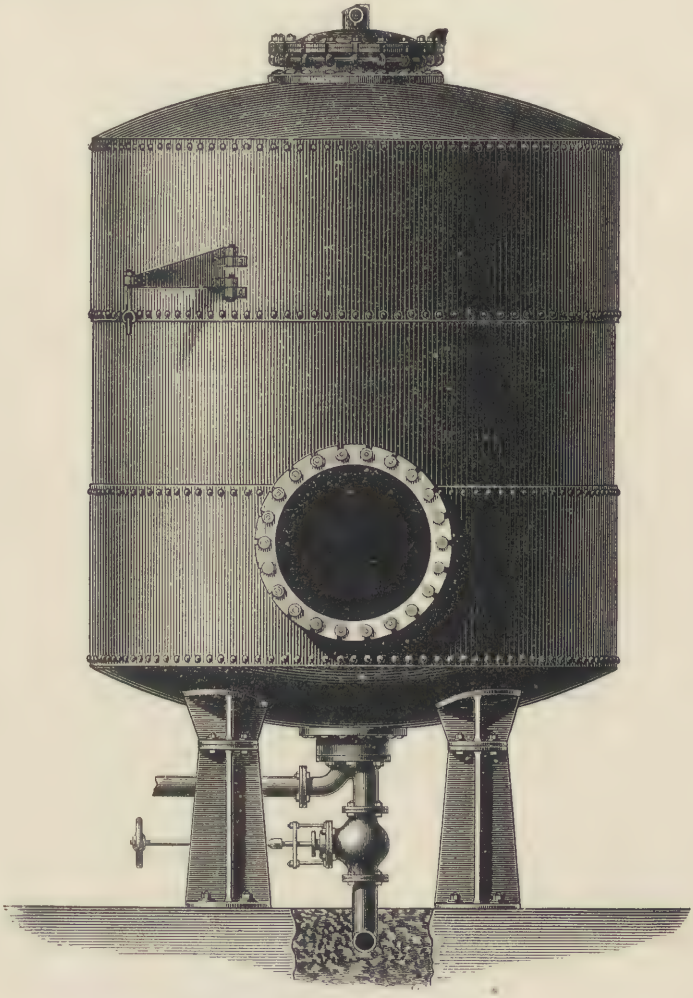


Fig. 35.—Stationary Straw-boiler.

The initial operations of dusting, removing dirt, weeds and other foreign matter are practically identical with those used in the treatment of esparto. The boiling, however, is seldom carried out in an ordinary upright stationary boiler, but in rotary digesters, spherical or cylindrical in shape, because, with straw cut up into short pieces by means of a chaff-cutter, the mass of heavy wet stuff does not permit of the free circulation of caustic soda by the vomit of the Sinclair boiler.

If, however, the straw is boiled without being cut up, it is possible to use the upright stationary digester.

The straw is boiled for about six to eight hours at pressures varying from 70 to 90 lbs. with a solution containing caustic soda equal to 18 or 20 per cent. of the weight of straw treated.

Washing.—The washing of boiled straw demands some care, because the pulp contains a large proportion of very short small fibres which escape with the washing water when an ordinary drum-washer is used. The greatest yield of paper-making fibre, both in the case of esparto and of straw, is obtained when the washing system is so arranged that the pulp remains stationary in a suitable tank, and is cleansed by a continuous flow of clean water.

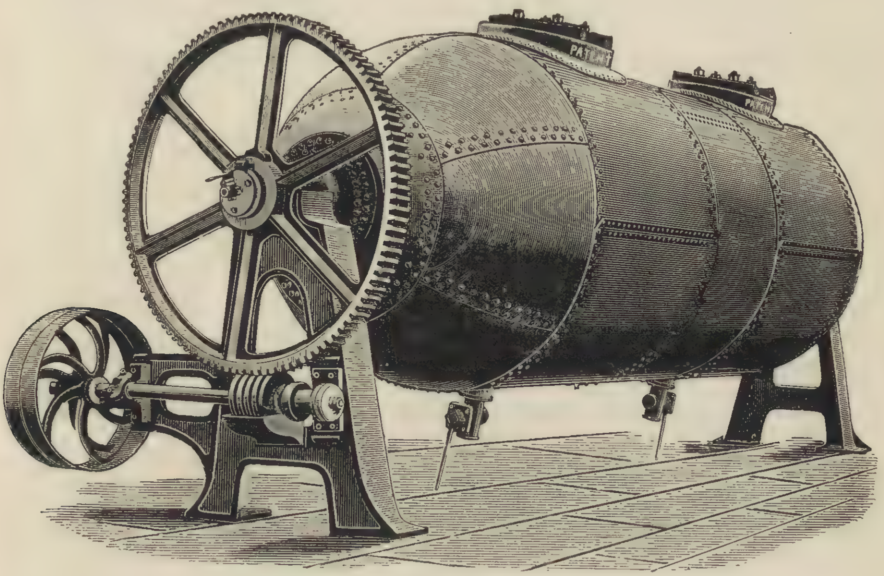


Fig. 36.—Revolving Cylindrical Boiler.

Bleaching, &c.—The final operations of bleaching, washing the bleached pulp, and producing the sheets of wet pulp for further use, resemble those applied to esparto. The quantity of bleach required entirely depends on the extent to which the straw has been boiled, since a well-boiled pulp may only require a small percentage, whereas an insufficiently digested straw will consume a larger proportion. Eight to twelve per cent. of bleaching powder is considered sufficient.

The table on pages 48 and 49 shows the conditions under which the various raw materials commonly used for paper-making are converted into pulp or "half-stuff."

Beating.

The process to which all bleached pulps or "half-stuffs" are submitted as being the next stage towards conversion into paper is known as "beating," an operation effected in the beating-engines or "beaters."

This term arises from the fact that, prior to the invention of a special machine based on the idea of rotating cylinders provided with steel knives to disintegrate rags, the bleached rag pulp was treated in a kind of mortar by means of

TABLE V.—*Statement respecting the Manufacture of Half-stuff.*

PROCESS.	RAGS.	ESPARTO.	STRAW.	SULPHITE WOOD.	SODA WOOD.	WASTE FIBRES.
Raw material.	New rag-cuttings. Old rags. Canvas, &c. White and coloured rags. Received in large bales.	Spanish and African grass packed in huge 4 cwt. bales.	Oat, wheat, barley, rye, packed in pressed bales. (Mostly prepared abroad.)	Pine, spruce, poplar, and other soft woods, in the form of logs.	Soft woods, mostly poplar, in the form of logs.	Waste papers, old jute bags, gunny, textile fibre wastes.
Preliminary treatment.	Dusting, sorting, according to colour and quality. Rags cut into small pieces by hand or machine.	Freed from dirt, sand, stones, by dusting in a "willow." Root-ends sometimes picked out.	Dusting, picking out of weeds and foreign matter. For special qualities, knots cut out.	All external bark removed by special machinery. Logs chipped into small pieces.	Logs carefully barked and chipped into small pieces.	Material cut up by suitable machinery into small pieces.
Boiling treatment.	Rags boiled under pressure in spherical revolving boiler, with chemicals.	Esparto boiled under pressure in stationary upright boiler with chemicals.	Straw boiled in horizontal cylindrical revolving boiler.	Wood boiled either for short time at high pressure, *or* for long time at low pressure.	Wood boiled for moderate length of time at a high pressure.	Jute and textile wastes boiled short time at moderate pressure.
Chemicals used. *Quantity.*	Caustic soda. 5–10 per cent.	Caustic soda. 15–18 per cent.	Caustic soda. 15–20 per cent.	Bisulphite of lime and sulphurous acid.	Sulphate of soda : caustic soda.	Caustic soda. 5–10 per cent.
Time. *Pressure.*	2 to 5 hours. 18–25 lbs.	4 to 5 hours. 40–50 lbs.	5 to 6 hours. 50–70 lbs.	See chap. v.	See chap. v.	2 to 5 hours. 5–15 lbs.

Cleansing treatment. (1) *Treatment of spent liquors.* (2) *Washing of the pulp.*	Spent liquors generally thrown away. Rags washed in tanks, then in potchers.	Spent liquors preserved, evaporated down and the soda recovered for further use. Fibre washed in boiler, or in tanks, or by special machinery.	Spent liquors preserved for recovery of soda. Fibre washed in tanks, or in potchers.	Spent liquors thrown away. Pulp washed in sand-traps, circular rotary washers, and tumblers.	Spent liquors preserved for recovery of soda. Pulp washed in tanks or in special vessels.	Spent liquors usually thrown away. Material washed in tanks or potchers.
Bleaching.	Chloride of lime solution added to pulp in potchers. When bleached, rags washed free of residues, sometimes by the aid of antichlor.	Chloride of lime solution added to pulp in potchers, or in steeping-tanks, or in patent circulating towers. Pulp then thoroughly washed.	Same as Esparto.	A great deal is sold unbleached. For bleached pulp, process same as Esparto.	Same as Esparto.	None as a rule.
Per cent. Bleach.	4–5 per cent.	5–10 per cent.	8–14 per cent.	7–18 per cent.	15–25 per cent.	Nil.
Yield of paper-making fibre.	75–80 per cent.	45 per cent.	40 per cent.	45–50 per cent.	45–50 per cent.	75–90 per cent.

a tight-fitting stamp. The complete disintegration of the half-stuff into fine pulp was thus accomplished by actual beating, there being an entire absence of any cutting action; but the process was very long and costly, though the paper obtained possessed remarkable strength and durability. An interesting account of this process will be found in a lecture read by Dr. Arnot before the Society of Arts in 1877.

Since the invention of the first beating-engine, constructed with a revolving cylinder fitted with steel knives about the year 1800, by the Dutch, many types and modifications of beaters have been introduced. In spite of the many years which have elapsed since the introduction of the "Hollander," as it is called, the original form of this early beating engine is found most suitable for the

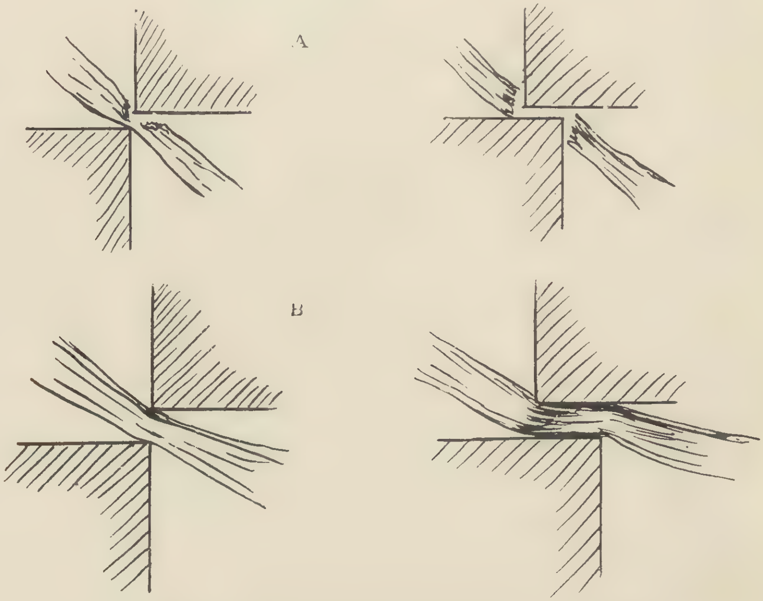


Fig. 37.—Diagram illustrating Effect of altering relative Position of Beater-knives on the Roll and Bed-plate. (Klemm.)

A. Knives in close contact, producing a cutting action.
B. Knives further apart, producing a rubbing or tearing action.

proper treatment of rag half-stuff, the later machines having certain advantages for other pulps only.

The "Hollander" Beating-engine.—This machine is an oval-shaped trough, similar in appearance to the "breaker," having semicircular ends, and divided into two channels or compartments by a "midfeather," which extends down the centre of the trough, but does not reach the full length from end to end. The beater-roll is constructed of such a size that it operates in one of the channels, revolving at a given speed in more or less close contact with a bed-plate fitted with stationary knives fixed to the bottom of the channel. The floor of this particular channel slopes gradually upwards towards the beater-roll, and then falls suddenly behind the roll, the curve of this "backfall" being similar to or concentric with the curve of the roll. The beater is thus in many respects closely allied to the breaker, but it differs in certain important

details. The knives are more numerous, and their arrangement in the beater-roll somewhat altered in order to produce the required beating of the pulp. The distance of the roll from the bedplate is capable of finer adjustment, and this is essential. (*See* Fig. 6.)

TABLE VI. *showing Time occupied in Beating.*

Hours in Beater.	Rags.	Wood pulp.
1		
	Blottings	Cheap blottings
2	Antiques	Antiques
		Tea, tobacco papers
3	High-class Printings	Enamelling papers
		Long elephants
4		Drawings, envelopes
	Heavy writings	Cartridges
5	Cartridges	Manilas
	Ledgers	Printings
6		Fine Manilas
	Thin writings	Writings
7		Imitation grease-proofs
		Fine cartridges
8	Thin opaques	
		Opaques
9	Banks	Banks, loans
	Loans	
10		Thin grease-proofs
	Thin banks	
11	and loans	

The Object of Beating.—The half-stuff obtained from the breakers cannot be converted into paper until the fibres have been more completely disintegrated. The treatment in the beating-engine not only reduces the fibres to any desired length, but in the case of rag pulp splits up the fibres at the ends into a number of small fibrillæ which are of great service in the formation of a strong sheet. Another effect of prolonged contact between the pulp and water in the beater is to produce some peculiar assimilation of water by the individual fibres which at present is not thoroughly understood, although its practical advantages are well known. (Fig. 37.)

The conditions of beating may be varied to almost any extent to suit the paper. For example, if half-stuff manufactured from old and tender cotton rags is put into a beating-engine provided with sharp knives and cut up very quickly, the pulp produced consists of short pieces, the ends of which are clean cut. When such pulp is run off on to the wire-cloth of a paper-machine, it parts readily with the water, and the stuff is then said to work very "free." Beating under these conditions is necessary for the manufacture of blotting papers.

If, on the other hand, half-stuff from strong rag is taken for the manufacture of banks and loans, the process is quite different. The beater-roll has to be lowered down into contact with the stationary bed-plate gradually, so that the fibres are drawn out and split lengthwise by the friction of the fibres upon one another.

The strong rag gradually disintegrated by slow beating in an engine provided with blunt knives becomes "greasy" to the touch, and will not part readily with the water. Such pulp is said to work "wet" because of the curious assimilation

of water by the individual fibres. The cellulose is said to be *hydrated*, but the actual nature of the change has not been thoroughly investigated.

The main factors which determine the variations possible in beating are: the condition of the knives, the rate at which the beater-roll is lowered upon the bed-plate, and the time occupied in treatment. A blotting paper requires short, sharp beating for about one and a half hours, while a bank or loan requires prolonged gradual beating for nine to ten hours.

Table VI. illustrates very roughly and approximately the influence of time in beating. The times stated are only approximate, since methods of treatment vary in different mills, and the half-stuff has to be selected carefully, with a view of producing the particular class of paper required.

It must be noted that while blottings take about one and a half hours, it cannot be assumed from this table that the rags suitable for blottings, if beaten nine hours, will produce strong banks. Rags which are essential for blottings would be useless for banks. Similarly a wood pulp suitable for an imitation grease-proof will not be of much use for the manufacture of an antique.

The paper obtained from pulp which has been submitted to prolonged beating is always more or less transparent, the fibrous structure being considerably modified. Wood pulp particularly is susceptible to this change, due, as already suggested, to the assimilation of water. This so-called *hydration* of the fibre is not brought about by the mere absorption of water by the pulp, as water is taken up by a sponge. In the latter case the action is purely a mechanical one, and the moisture can be removed by mechanical means, that is, by pressure, whereas with the beaten pulp the change is by no means so simple. If it were, then the mere immersion of the half-stuff in a tank of water four hours, followed by four hours beating, might be expected to give results similar to those obtained by taking the half-stuff direct from breaker to beater and beating at once for eight hours.

If the beating operation is carried to an extreme, and the rag or wood pulp beaten for twenty-four to thirty-six hours, the fibres become so greasy that it is almost impossible to make a sheet of paper from the pulp. The physical structure of the fibre is practically destroyed, and the wet pulp, on exposure to air, gradually shrinks down into a small compact mass, which, when dry, is hard enough to be put in a lathe and turned.

The Effect of Beating on various Fibres.—Since the physical characteristics of paper-making fibres differ very widely, it is not surprising that the process of beating requires to be carefully modified to suit them. Cotton and linen, having fibres of maximum length, are naturally capable of yielding a greater number of varied qualities of paper, according to the conditions of treatment in the beating-engine.

Chemical wood pulp may also be manipulated for the production of a variety of papers, differences in effect being controlled, not only by methods of beating, but also by the nature of the wood and the conditions of boiling.

Esparto and straw being extremely short fibres cannot be altered to any great extent by beating, the action of the beater-roll being confined mainly to a more complete isolation of the single fibres, and when this disintegration has been effected the pulp is ready for conversion into paper.

Mechanical wood pulp, a structureless mass of torn fibres, sometimes very coarse and woody, sometimes very short and floury, with but little felting power, suffers little alteration by beating, and no good purpose is attained by any prolonged treatment.

CHAPTER V

WOOD PULP

Mechanical wood pulp—Logs—barking, grinding, boiling, screening, pressing
Chemical wood pulp—Logs, chipping, screening, pressing, making dry pulp sulphite liquor.

Mechanical Wood Pulp.

THE paper-making fibre known as mechanical wood pulp is so called because prepared by a purely mechanical method, in contradistinction to pulp manufactured

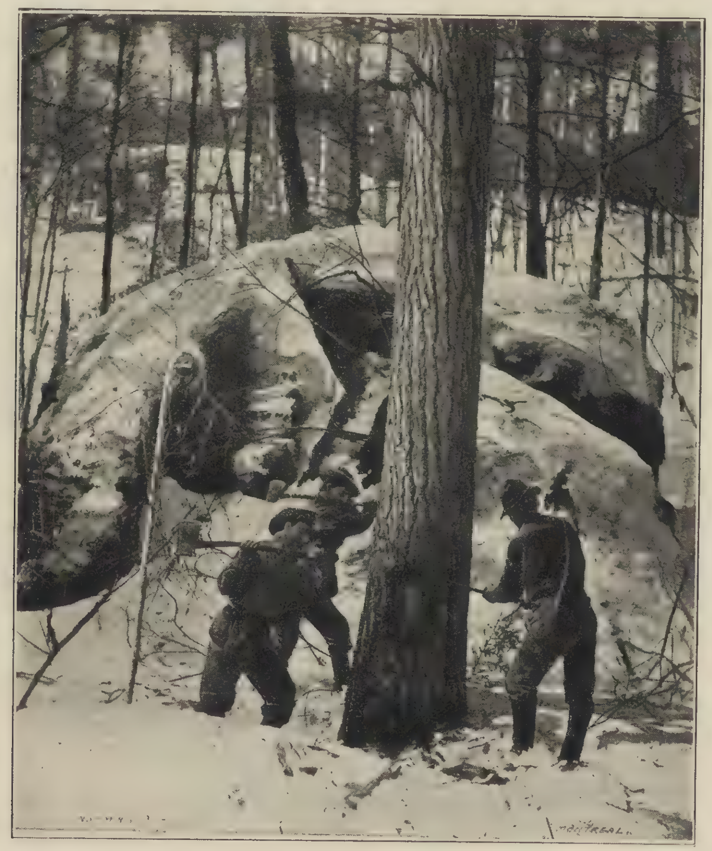


Fig. 38.—Men cutting down a Tree.

by chemical processes. It is often described as *ground* wood, a term which has been applied to it from the fact that the raw wood is ground into pulp. The pulp is of inferior quality, not only in regard to its chemical constitution, since it contains all the resinous and gummy matters of the original wood, but also as to its physical structure, the disintegrated fibres being inflexible, short, and of irregular shape, possessing very little "felting" property.

The composition of the prepared pulp is such that the papers containing it cannot be relied upon to keep their colour, strength or texture for any long period. The presence of *mechanical wood* pulp in a paper favours the conditions for gradual decay and ultimate disintegration, and the period for complete destruction is roughly proportional to the percentage of ground wood in the paper. The progress of such disintegration is hastened by the presence of

Fig. 39.—Logs on Bank of River.

ordinary rosin size, especially when the papers are freely exposed to sunlight, and to normal atmospheric conditions.

Logs.—Trees are cut down in the winter time by gangs of men, and piled up on the frozen rivers until the spring. Then they gradually find their way to the mill. The logs of wood brought into the pulp-mill are usually 12, 14 or 16 feet long. These are cut up into short lengths of two feet by means of powerful circular saws, all rough and awkward pieces being thrown aside and subsequently utilised as fuel.

Barking.—The two-foot pieces are then "barked," a process by means of which the outer bark is removed from the wood. Two methods are in common use, namely, the "tumbler" system, and the "barker" system. In the former, the short pieces are thrown into a large revolving cylindrical drum, together with a suitable quantity of hot or cold water. The friction of the pieces against each other, due to the tumbling caused by the rotation of the drum, completely removes the bark, and the logs are withdrawn in a clean condition. In the

"barker" system, the removal of the bark is effected by a different method altogether. The machine used consists of a heavy iron disc provided with three strong steel knives fixed to its surface, and projecting about half an inch from it. The disc rotates very rapidly in a vertical position, and when the piece of wood is pressed against the surface, the bark is removed by the knives, which shave it off completely. (Fig. 40.)

The loss of wood entailed by this second barking process is considerable, particularly when the logs are small or crooked, as it is then impossible to avoid cutting away a proportion of the actual wood in addition to the bark. At the

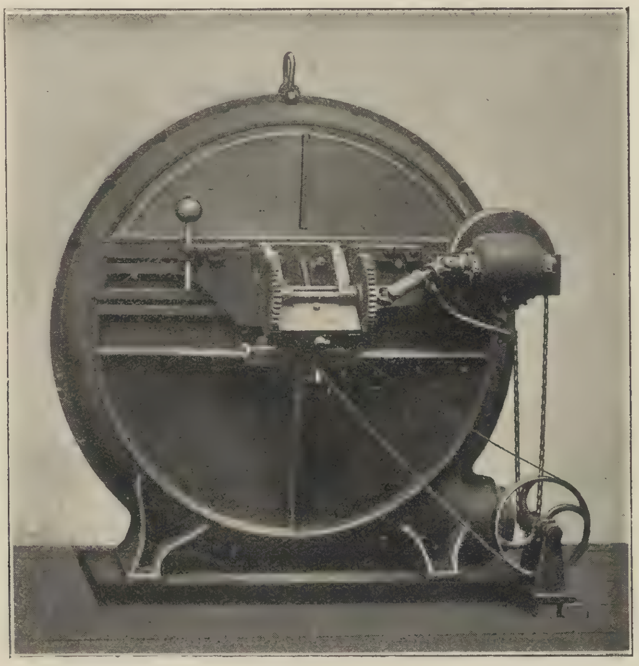


Fig. 40.—Machine for removing Bark from Logs.

same time the logs are more thoroughly cleaned and defective places in the wood more completely removed. The loss varies from 25 per cent. for small or crooked logs to about 15 per cent. for large well-favoured pieces. The barked wood is then ready for grinding.

Grinding.—Although the process is a comparatively simple one in principle, yet there are many practical details which demand attention if the pulp is to be satisfactory.

There are several types of grinding machinery used, but they are all based upon the plan of forcing the wood by means of hydraulic pressure against the face of a rapidly revolving grindstone continually flooded with water, which carries away the disintegrated pulp as fast as it is produced.

The grindstone is a massive heavy stone about 54 inches in diameter and 27 inches thick. It is mounted on a steel shaft and covered with a specially-built iron casing. This casing is provided with several projecting chambers or pockets,

into which the wood is thrown, in such a manner that the side of the log comes into contact with the face of the stone, against which the wood is forced by the hydraulic cylinders attached to the pockets. In some machines the stone revolves in a horizontal position, while in others the stone rotates in a vertical position, the former appliances being used chiefly in Scandinavia, the latter both in Scandinavia and in America. (Fig. 42.)

The fibres of the wood are torn away from the logs by the friction of the stone, and the constant stream of flowing water carries the pulp into a pit below the grinder. When a considerable quantity of water is used in this way, the

Fig. 41.—Grinder Room.

pulp is kept at a normal temperature, but by limiting the proportion of water the pulp acquires a thick consistency and its temperature is raised to such an extent that it is impossible to keep the hand immersed in it any length of time. This class of pulp is made on the vertical stone grinders and is known as "hot-ground" pulp.

The pieces of wood used vary in diameter from 4 inches to 24 inches. In the latter case the pieces are split into sections by means of a log-splitter. (Fig. 43.)

Screening.—The pulp flows from the grinders over a coarse sieve which retains any large splinters or chips, and it is then carefully screened. The screens used for this purpose are shallow iron boxes, the bottoms of which are brass plates grooved all over with very narrow slits. These plates are kept in a state of violent agitation by suitable mechanism so that the fine pulp passes through the slits and the coarser pulp remains on the surface of the plates. This

coarse pulp is sometimes converted into finer pulp by means of a Jordan engine and screened over again in order to prevent waste. Another method of screening is the use of what is known as a "shaking sieve." The pulp flows on to a long brass plate in which the usual holes or slits have been cut. The box is

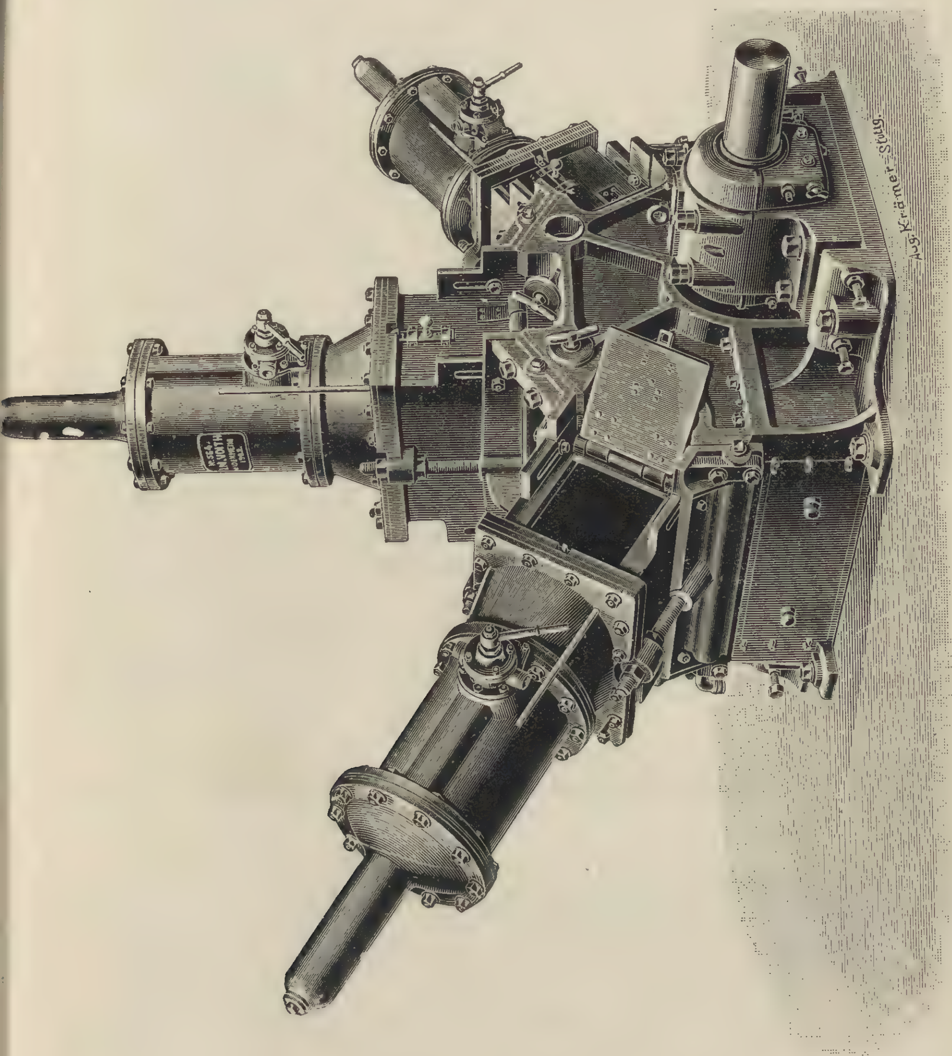


Fig. 42.—Grinder.

placed in a sloping position with the lower end open, so that the stream of fine pulp and water falls through the slits, leaving the coarse pulp on the surface of the plate, and this gradually works down towards the open end of the box, where it falls into suitable receptacles. There are other varieties of apparatus and numerous differences in the practical methods employed which it is unnecessary to give in detail. (Fig. 44.)

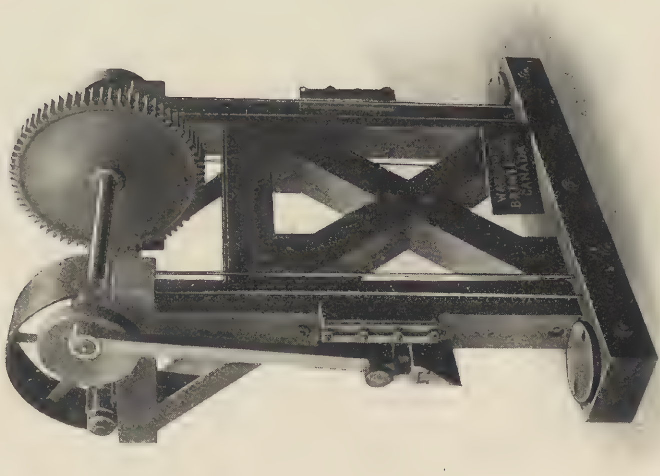


Fig. 43.—Log-splitter.

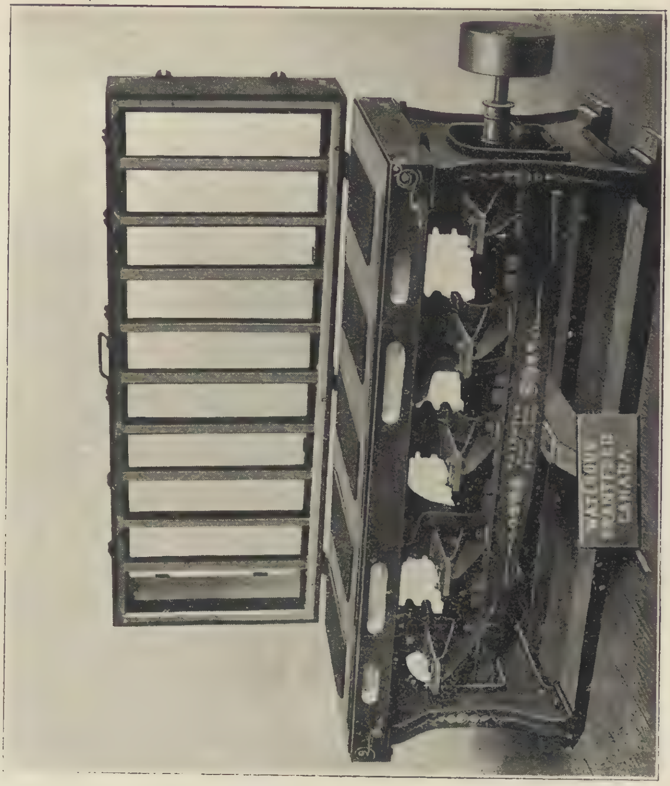


Fig. 44.—A Pulp Screen.

Pressing.—The proportion of water to pulp at this stage in the manufacture is so large that it is necessary to pass the mixture through a machine which removes the water and produces the mechanical wood pulp in a more solid form for marketable purposes. This is effected by means of a wet press machine, shown in Fig. 45.

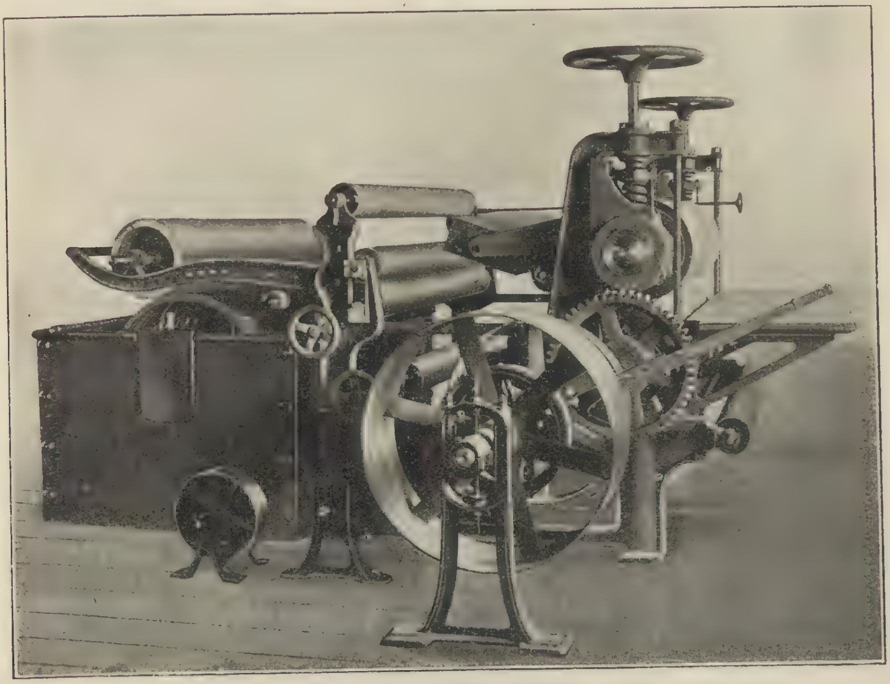


Fig. 45.—Wet Press Machine.

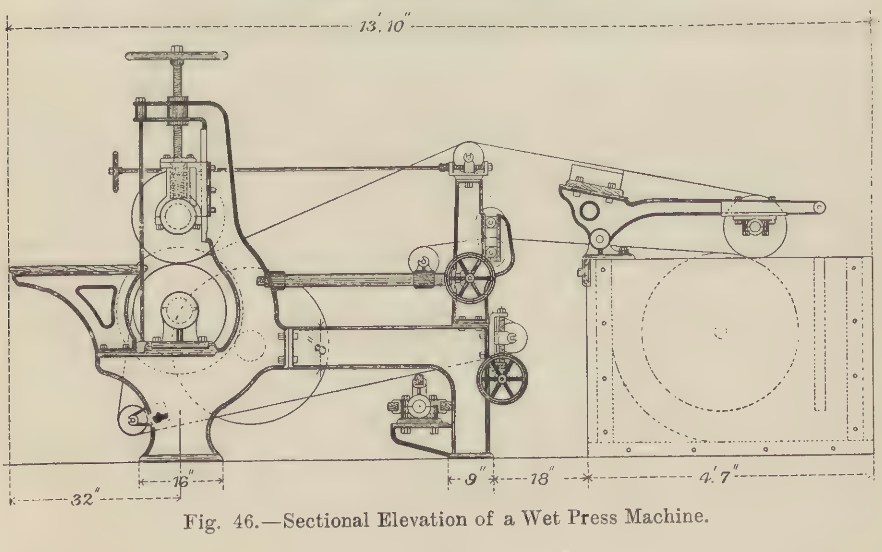


Fig. 46.—Sectional Elevation of a Wet Press Machine.

The mixture of pulp and water flows into a large wooden tank in which slowly rotates a hollow cylindrical drum, covered with fine wire-cloth. The water passes through the wire, but the pulp adheres to the surface of the drum in the form of a thin skin. The water is regularly discharged from the central axis of the drum as fast as it gets through the wire, and the skin of the pulp is carried up by the revolving drum above the surface of the mixture in the tank, where it comes into contact with an endless travelling felt or blanket to which it adheres. The drum continually revolves and produces an endless skin of pulp, which is constantly transferred to the felt. The pulp carried by the felt is passed between two rollers, which squeeze out more water, and at the same time

Fig. 47.—Hydraulic Press.

the pulp adheres to the upper roller, leaving the clean felt to travel back over the lower roller to the hollow drum. The pulp is wound round the upper roll until a sufficiently thick sheet is produced, and then it is cut off. The amount of water in the pulp at this stage is about 70 per cent.

The thick sheets are folded up into a convenient size, usually 24 inches long by 18 inches wide, and piled up into a small stack, which is at once submitted to great pressure in order that the quantity of water may be still further reduced. By this means a pulp is obtained consisting of 50 per cent. air-dry fibre and 50 per cent. water. (Fig. 47.) After packing, the pulp is ready for export in the form of a bale of moist sheets. Mechanical wood pulp intended for the manufacture of paper is seldom prepared in the dry state, as there are many practical disadvantages in the subsequent manipulation of the pulp.

On this account the testing of wood pulp for the amount of moisture is an important part of the work of the paper-mill chemist.

The Manufacture of Chemical Wood Pulp.

Pulp prepared by treating wood with various chemical reagents under proper conditions is termed chemical wood pulp in order to distinguish it from pulp manufactured by the mechanical process already described. There are several methods employed for the production of paper-making fibre from wood, but the *sulphite* process is the best known and most universally adopted.

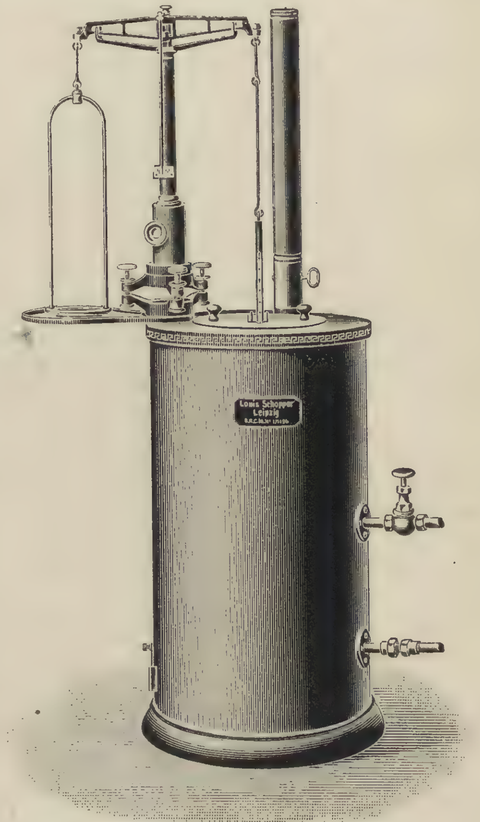


Fig. 48.—Schopper's Oven for testing Moisture in Wood Pulp.

Logs.—The logs of wood used for the manufacture of both chemical and mechanical pulps are subjected to precisely the same preliminary treatment. They are sawn up and barked, as shown above, and used indifferently in either process. As a rule, the short two-foot pieces are roughly sorted, so that the clean logs, free from decaying knots, may be preferably used for chemical pulp. In some cases the knots are bored out, but this is an expensive operation and only applied under special circumstances.

Chipping the Logs.—The short logs are next chipped up into small pieces or flakes about one inch square and a quarter of an inch thick by means of a powerful machine called a chipper. This is a massive iron disc rotating rapidly in a vertical position, being partially encased by an iron cover. From the surface of the disc project three steel knives, similar to those used in the barker, except that the knives are placed much closer to the centre of the disc to minimise the strain produced on the machine during use. The log is thrown into a short iron tube, which forms part of the casing and which is inclined at an angle of forty-five degrees to the surface of the disc, so that the wood is chipped into flakes at that angle. The wood is continuously discharged from the chipper and transferred by travelling belts or any convenient form of conveyer to the digester-house, where it is usually stored in huge wooden bins erected over the mouth of each digester.

Chemical Process.—The next operation involves the digestion of the wood with a chemical solution at a high temperature. The details of carrying out this digestion process vary considerably, the differences relating chiefly to the time of boiling, the temperature, and the strength of the chemical solution. As a

general rule, with the stronger liquors and higher temperatures the operation is more quickly carried out, but the product is not invariably of the highest quality. Two systems of digestion are in vogue, viz., the Mitscherlich or "slow-cooking" process, the second being known as the "quick-cook" or high pressure method.

High Pressure System.—The digester, which is a tall cylindrical steel vessel, averaging 14 to 15 feet internal diameter, with a height of 50 feet, lined with special acid-resisting brick, is almost completely filled with the chips of

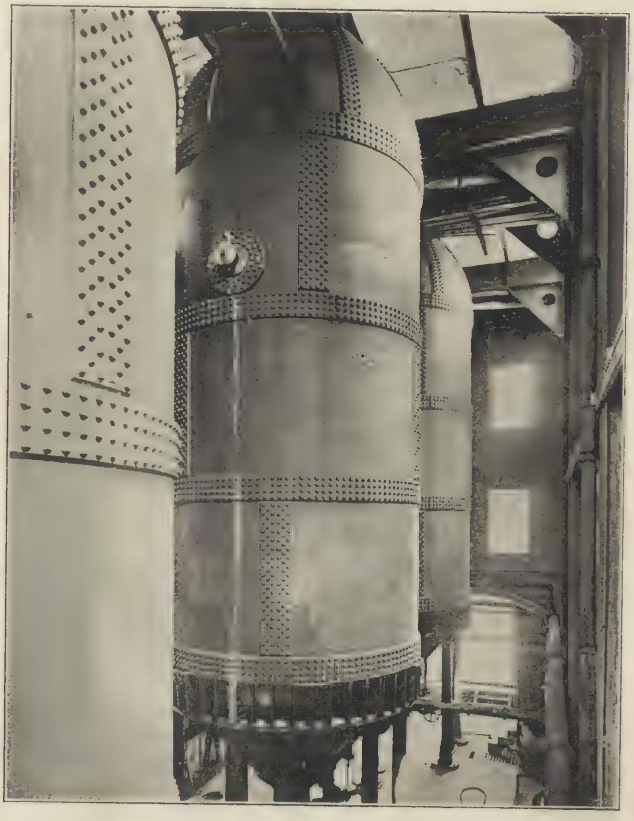


Fig. 49.—Sulphite Digesters.

wood, and the liquor run in as quickly as possible. After the man-hole has been closed down, high pressure steam is blown direct into the digester and the contents boiled for a period of eight to ten hours. By this means the wood is reduced from its original hard condition to a soft pulpy mass.

The progress of the "cook" is carefully watched, especially towards the end of the operation, small quantities of the solution being withdrawn and tested at intervals. When the pulp is digested to the required extent, the contents of the digester are blown out under pressure into huge washing-tanks. The spent liquor drains away from the pulp and the latter is thoroughly washed with clean water.

It is interesting to note that about 50 per cent. of the actual weight of wood is dissolved by the chemical liquor. At present there is no systematic method

for the treatment of the waste liquors with a view of recovering any by-products. Attempts have been made from time to time in this direction and certain substances have been obtained which find a limited use, but so far no general and practical method has been found, and the importance of the question may be judged from the fact that the loss entailed includes not only one-half the weight of wood put into the digester, but also the loss of about 300 lbs. of sulphur for every ton of pulp produced.

Screening.—The pulp having been thoroughly washed is carefully screened in order to remove knots and other portions of incompletely boiled wood. Many systems are in use for efficient screening, and one of the simplest methods employed

Fig 50.—Openings to Digesters.

is to pass the whole of the pulp over a series of screens, some of which are very fine and only allow the best quality of fibre to pass through, while others are coarser and give a pulp of somewhat inferior character, but suitable for common papers. The "Success" screen consists of brass plates, in which are cut a number of fine slits, and these plates are fitted into an iron frame so constructed as to form a shallow box. The bottom of the box, fitted with the brass plates, is kept in a state of violent agitation, so that the fine pulp finds its way through the slits while the coarse pulp is prevented from passing away.

Pressing.—As the proportion of water to pulp at this stage is very large, the whole of the diluted pulp is next run through a wet press machine in order to separate out the pulp.

The pulp as it is taken from the wet press machine contains about 70 per cent. of water, and part of this is further removed by means of the hydraulic

press, and the moist sheets containing 50 per cent. of water are then packed up into bales ready for export.

Most of the sulphite pulp, however, is shipped from the pulp-mill in a dry state. In this case the process described is modified as follows:

Making Dry Pulp.—The washed pulp taken from the digesters is carefully screened and then run off into large tanks, or chests, and converted into sheets on a machine which closely resembles an ordinary paper-machine, the diluted mixture of pulp flowing on to an endless wire-cloth to which is imparted a shaking motion. The water drains away, leaving the pulp on the upper surface of the wire in the form of a sheet. Further quantities of water are abstracted by means of a vacuum box, placed under the wire, and the moist sheet so formed

Fig. 51.—Sulphite Pulp-drying Machine.

is pressed between rollers and led over a number of large steam-heated cylinders. The sheet of pulp is thus completely dried, and as it reaches the end of the machine it is automatically cut into sheets of the required size.

Sulphite Liquor.—The liquor used for digesting the pulp is known as bisulphite of lime. It is prepared by bringing the vapour of burning sulphur into contact with lime and water. In the "Tower" system, ordinary flowers of sulphur are burned in a specially constructed oven, and the sulphurous acid gas obtained is led away into tall towers filled with huge lumps of limestone, which are kept in a moist condition by a stream of water flowing from tanks at the top of each tower. As the gas passes upwards through the limestone it enters into combination with the water and lime, the whole of the gas being absorbed so that the liquid flowing out at the bottom of the tower is a strong solution of bisulphite of lime of constant strength. This is pumped into store-tanks and run into the digesters as required.

In the "Tank" system the gas is simply pumped into large circular vats in

which ordinary powdered lime mixed with water is kept in a state of violent agitation. The gas enters into combination with the milk of lime, giving a solution of bisulphite of lime.

The amount of sulphur required to produce a ton of air-dry pulp varies between 350 and 300 lbs.

"Mitscherlich" Process.—A wood pulp particularly suitable for certain special papers is prepared by this method due to Mitscherlich. The conditions of digesting are radically different from those employed in the manufacture of the ordinary sulphite pulp, the pressure being seldom above 15 lbs., and the time

Fig. 52.—Sulphur Ovens.

occupied by the "cook" averaging about thirty-six to forty-eight hours. Moreover, the steam does not come into direct contact with the contents of the digester, but passes through a lead coil, while the condensed water produced flows away.

The pulp is not blown out of the boiler under pressure, but is removed by shovels and rakes through a large man-hole near the bottom of the boiler after the pressure has been reduced. The pulp is partly washed before it is taken out of the digester, and more thoroughly washed afterwards in very long shallow "Knot" catchers, which retain hard unboiled chips and knots, and allow the properly digested pulp to flow out.

Soda Pulp.—The ordinary commercial soda pulp is a soft brown-coloured fibre of excellent quality which is useful for the production of bulky papers. The word "soda" is a somewhat comprehensive term applied in a general way

Fig. 53.—General View of a Sulphite Mill.

to the process, although the substance used in reducing the wood to pulp is not always caustic soda. The chipped wood is put into the digester, which is usually a horizontal cylindrical rotary about 22 feet long and 7 feet in diameter, the requisite quantity of chemical solution being added and then treated by steam to a pressure of 90 to 100 lbs. for thirty hours.

The solution is made by mixing sulphate of soda with caustic soda, but in subsequent operations the spent lyes from the digesters are evaporated down, the residues incinerated by methods used in the recovery of esparto liquors and the resultant ash dissolved, rendered caustic by boiling with lime, and used over again. Mechanical losses in treatment are made up by additions of fresh sulphate of soda.

Wood is also converted into pulp by treatment with caustic soda in the same way as esparto and straw, the amount of caustic soda being greater, and higher pressures being employed. This method is the true soda process, and is now largely used for the reduction of woods other than spruce. In fact the "sulphate" pulp is not produced in any great quantity.

CHAPTER VI

WOOD-PULP PAPERS.

Selection of wood pulps—Varieties of wood pulps—Nature of papers produced—Process of manufacture—Writings and high-class printings—News and common printings.

Selection of Wood Pulps.—The fibre obtained by the chemical treatment of wood is capable of yielding a great variety of different papers according to the methods adopted for isolating the cellulose from the raw material, and the processes used for converting the fibre into paper.

The paper-maker exercises the same care in the selection of wood pulp for the manufacture of certain qualities of wood-pulp papers as he applies to the sorting and selection of rags for various rag papers, since in this way he can secure the desired results.

The table given on page 51 clearly shows that the wood can be treated so as to give as great a range of papers as rag. The variations are possible because the conditions can be changed, such as the nature of the wood, the chemicals used, the duration and extent of the chemical treatment, the process of bleaching, and last, but not least, the operation of beating.

The selection, therefore, of the most suitable pulp requires considerable care and experience. It must not be assumed from the table referred to that *beating* is the main factor. A wood pulp which will give a good *blotting* or *antique* will not produce a *grease-proof* or *loan* by the mere prolonging of the beating process, for the pulp would simply be "knocked all to pieces," to use a beaterman's phrase; and similarly, a hard strong sulphite pulp will not make an antique by beating during the period stated in the table. The proper pulp must be selected for the purpose.

Varieties of Wood Pulp.—The several varieties of pulp from wood, together with the classes of paper for which they are generally considered suitable may be classified somewhat as follows:

Soda wood pulp from poplar.—A soft, spongy pulp, which can be used for the manufacture of blottings, antiques and magazine papers, in which bulk, open texture, and soft handle are the qualities most desired. A pulp which is the best known imitation of esparto.

Soda wood pulp generally.—The pulp prepared by the soda process is favoured because it imparts *bulk* to the sheet of paper, and renders the sheet more opaque than the ordinary sulphite pulp.

Easy bleaching sulphite pulp.—A material which is prepared by cooking the wood to a soft condition, continuing the operation of boiling beyond the time required for an average strong wood pulp. Suitable for writing and high-class printings in which good colour and surface are essential.

Strong sulphite pulp.—A pulp which is strong and hard, produced by under-cooking rather than over-cooking the wood. The cellulose obtained is not so pure as that derived from a well-boiled material, nor is the colour absolutely

white, but the fibre is very suitable for news, cartridges, and manilas, in which strength is the main quality needed.

Mitscherlich pulp.—A wood cellulose prepared by the "slow-cook" process, and used chiefly for hard papers, as banks, loans and imitation parchments.

Papers.—Wood pulp is used by itself, or mixed with rags, esparto and hemp in varying proportions, according to circumstances. The greater portion of the wood pulp imported into this country is converted into news and cheap printings, which consist of mechanical and unbleached sulphite pulps in the ratio of about three to one, the average newspaper consisting of 70 per cent. mechanical, and 30 per cent. sulphite.

Used in combination with esparto, chemical wood pulp gives an excellent material for book papers, and for writings. The unbleached chemical woods are largely employed in the manufacture of wrappings, and packing papers of every description.

Some approximate idea of the result of combining the various wood pulps commonly used for paper-making may be gathered from Table VII.

TABLE VII.

Pulp.	How used or blended.	General Character of Paper produced.
Unbleached soda	By itself, or mixed with unbleached hemp and jute	Wrappers, browns, cable and insulating papers.
Bleached soda	By itself, or mixed with esparto	Soft bulky papers such as blottings, antiques, magazines and soft printings.
	Mixed with sulphite or rag	Writings and printings, envelopes.
Unbleached sulphite	By itself, or mixed with Mitscherlich sulphite wood pulp	Caps, packing papers, parchments.
	With mechanical wood pulp	News, cheap printings.
	With rag or unbleached hemp and jute	Cover papers—generally.
Bleached sulphite	By itself, or with rag pulp	Printings, writings, tissues, banks, book-papers, &c.
	With mechanical wood	Ordinary printings.
	With esparto and rag	Printings, writings, lithographic, &c.
Mitscherlich sulphite	By itself	Parchments and grease proofs.
Mechanical wood	By itself, or mixed with unbleached hemp and jute	Boards, cards, middles, tickets, browns and wrapping papers.

Writings and High-class Printings.—The treatment of chemical pulps for the manufacture of wood-pulp paper is practically the same, in general principle, as that described in chap. iv. dealing with esparto papers.

The pulp arrives at the paper-mill in the form of dry or moist sheets, which are first broken up in the ordinary breaking-engine, and if necessary bleached with chloride of lime. The best results in bleaching are obtained by adding the requisite amount of bleach liquor to the pulp in a washing-engine or potcher, discharging the mass into a large brick or cement tank at once, and allowing the action to proceed quietly with the pulp remaining motionless.

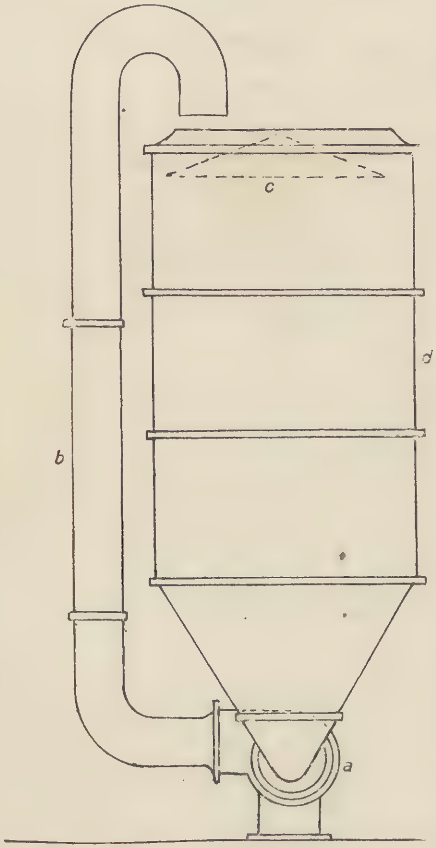


Fig. 54.—Bleaching Tower.

a. Centrifugal pump.
b. Circulating pipe.
c. Spreader.
d. Reservoir of pulp and bleach.

The process may be hastened by means of the "Tower" system of bleaching. In this case the pulp is pumped from the potcher or breaking-engine into a tall cylindrical tank of seven or eight feet diameter, and kept in a continual state of motion by a centrifugal pump fixed at the bottom of the tank. The pump causes the mixture to circulate from the bottom through a pipe back into the open top of the tank, and to fall upon a round plate which spreads the pulp over the surface of the mass in the tank. (Fig. 54.)

Beating.—The bleached pulp is thoroughly washed, run off into drainers, and afterwards transferred to the beaters.

Of recent years many types of beaters have been introduced for the treatment of wood pulp, the improvements being generally devised for the purpose of lessening the cost either by hastening the operation or by reducing the amount of power necessary to beat the pulp to a proper consistency. In the Hollander and Umpherston beaters, which have already been mentioned, the beater-roll fulfils two distinct functions, namely, the beating of the pulp and the circulation of the mass in the engine. In modern beaters the circulation of the mass is effected by some mechanism, such as an Archimedean screw or a centrifugal pump, and the beating is effected by the beater-roll, so that the latter is confined to its proper duty. The construction of the "underflow" type of beater, as it is sometimes called, can be seen by a study of the diagram in Fig. 55.

A modified form of this type of machine is the "Tower" beater. (Fig. 56.)

The stock of pulp in the cylindrical reservoir is kept in circulation by a

centrifugal pump fixed at the bottom, and is discharged from it continuously to the beater-roll, which is erected above the level of the reservoir.

A refining-engine is also used for the beating of wood pulps. It is a conical vessel lined with fixed projecting knives, and fitted with a beater-roll which is also conical. The roll is fitted with knives, and is so constructed that the distance between the rotating knives on the roll and those on the outer casing can be altered at will. This machine is very effective in brushing out the pulp, which is first partially treated in a beater. (Fig. 57.)

Sizing, Loading and Colouring.—These operations are similar to those employed with esparto papers. The loading is incorporate with the pulp in

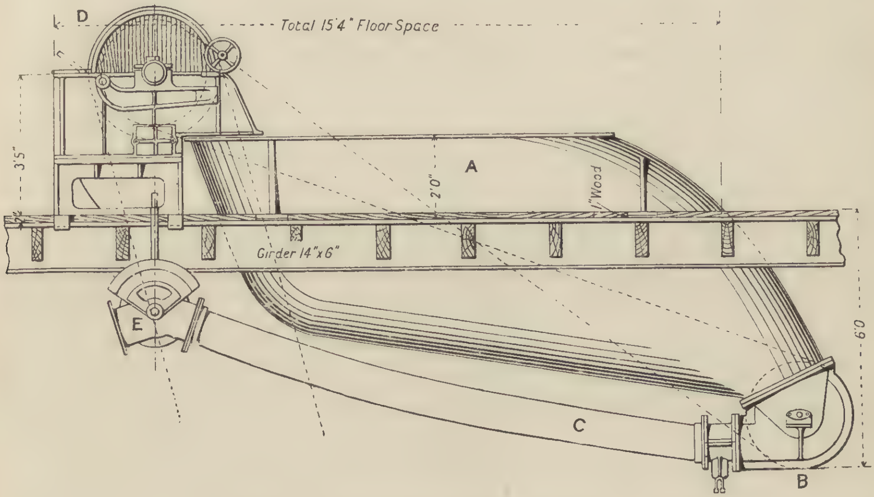


Fig. 55.—Taylor's Underflow Beater.

A. Vat containing pulp.
B. Circulating pump.
C. Return pipe.
D. Beater roll.
E. Discharge outlet.

the engine, the rosin soap is then added and precipitated on the fibre by means of alum. Pulps intended for white papers are toned by the addition of traces of aniline blues and reds.

News and Common Printings.—The cheap papers of the present day are made almost exclusively from sulphite wood pulp and mechanical wood pulp blended in varying proportions.

The extensive use of mechanically prepared pulp for paper-making is entirely a matter of commercial consideration, since the material is cheap and abundant, but from a technical standpoint it cannot be too strongly condemned on account of the deterioration which always takes place in paper containing ground wood.

Among other causes which have contributed to the cheap newspaper of modern times, improvements in machinery and mill organisation required for the production of a cheap paper take a foremost place. There is no special trade secret to be carefully hidden from the observant spectator, for the manufacture of a common news is now almost entirely a mechanical and engineering problem in which chemistry *appears* to play a secondary part. These improvements are mainly concerned with the machines used for preliminary operations and enlargements and alterations in the Fourdrinier machine. The use of beaters giving

etreater output is one of the most important features of recent development; ah adoption of rotating circular self-cleansing strainers for the beaten pulp passing on to the paper-machine is another improvement. (Fig. 58.)

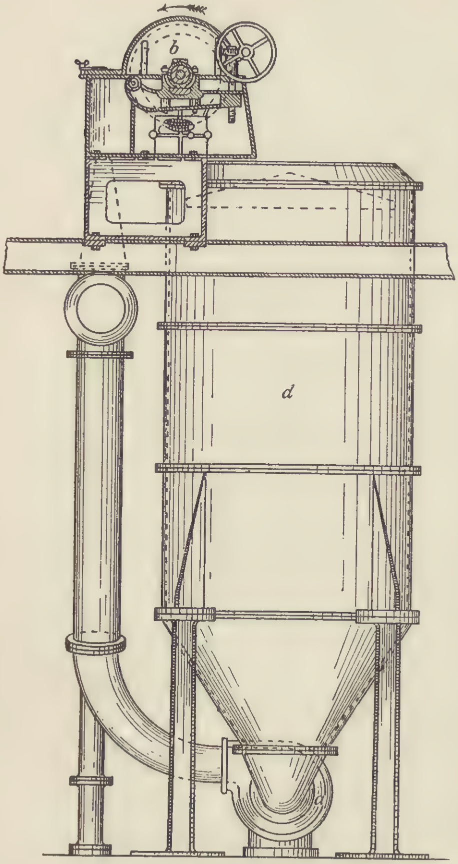


Fig. 56.—"Tower" Beater.

The paper-machines have been increased in width until it is now possible to make a reel of paper 150 to 160 inches wide. The speed of the machine is 420 to 480 feet per minute instead of the modest 250 to 300 feet per minute of ten or fifteen years ago.

The drying-cylinders have been increased both in size and number, and improved in design to meet the extra work of evaporation rendered necessary by the greater speed. Careful attention to the details of transport of raw material, economy in the use of coal, the utilisation of every conceivable waste product, such as the machine backwater, the exhaust steam used for driving the machine engine, the waste heat of the gases in the boiler flues, and many other details of a highly interesting and technical character, has resulted in the production of the cheap newspapers.

Manufacture of news.—The pulp is broken up as usual in some form of disintegrator, such as a breaking-engine or potcher. The engine is partially filled with water, and the sheets of mechanical pulp thrown in, together with the proper proportion

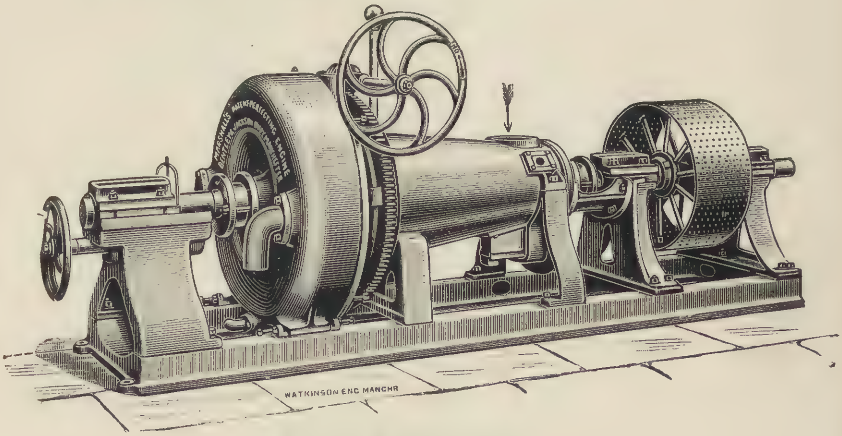


Fig. 57.—Refining-engine.

of sulphite. The quantities vary according to the quality of the paper, 65 to 75 per cent. of mechanical pulp being an average amount.

In many cases the mechanical pulp is broken up by special machinery instead

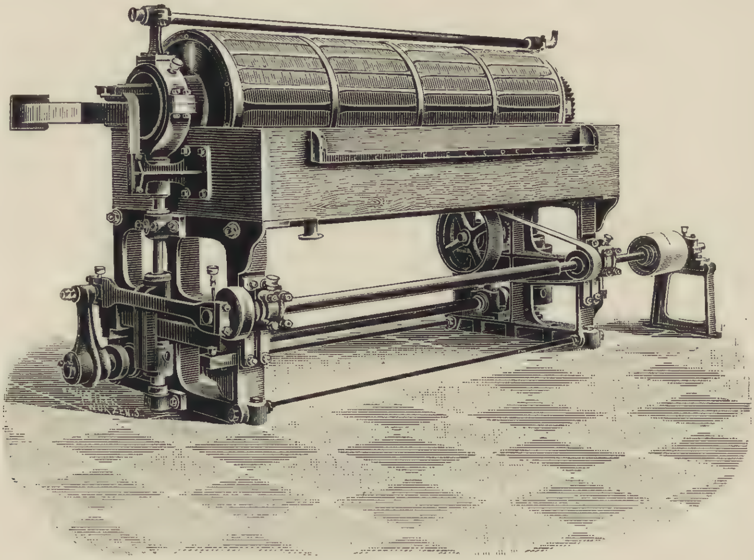


Fig. 58.—Rotating Strainer. Specially suitable for "News" paper. The pulp after beating is passed through this strainer.

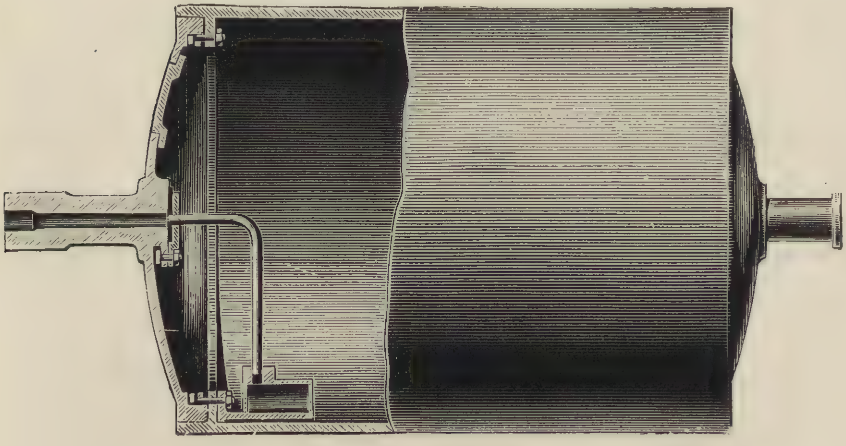


Fig. 59.—View of Drying-cylinder, showing Internal Arrangements.

of potchers, such as Wurster's kneading-engine (Fig. 61) or Cornett's breaker, both of which are useful for disintegrating pulp or waste papers.

The pulp is then discharged into the beating-engine, where it is beaten, sized, coloured, and mixed with china-clay.

Fig. 60.—Calenders at the End of a "News" Machine.

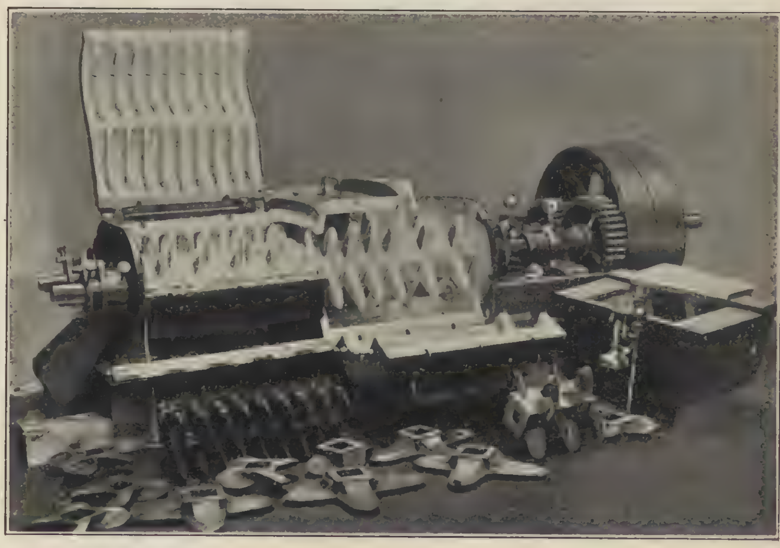


Fig. 61.—Wurster's Kneading-machine.

The conversion of the beaten stuff into paper is a simple matter as far as the general principles of treatment are concerned, but in questions of detail relating

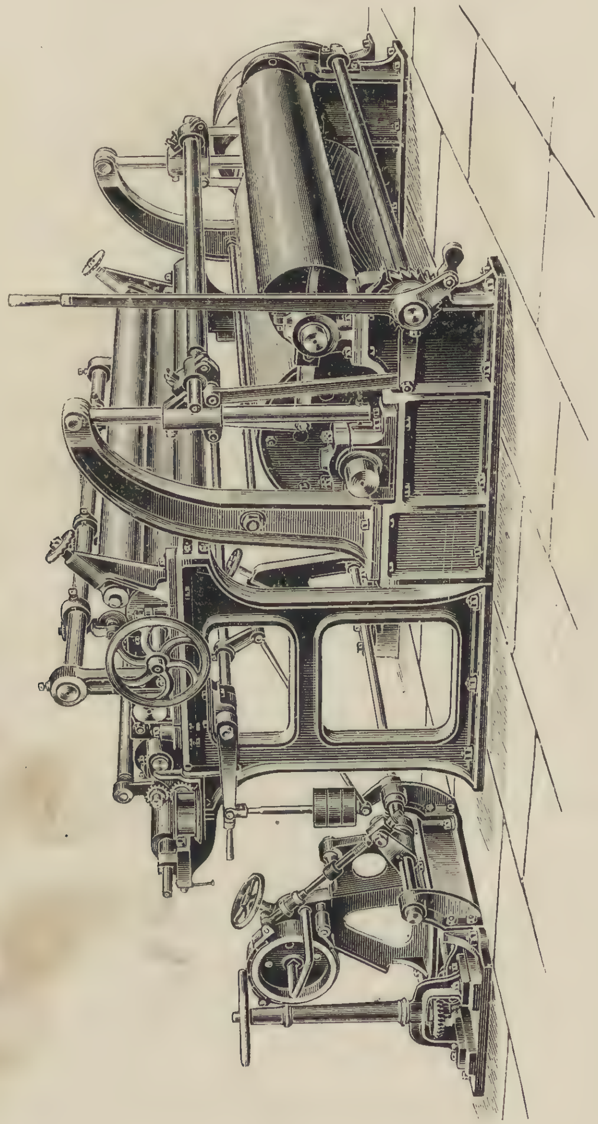


Fig. 62.—Double Drum Reeler. The reels from the paper-machine are re-reeled, slit and finished off on this machine.

to the running of the paper-machine considerable skill is requisite to avoid faulty paper and undue waste of material.

The manufacture of 100 tons of news requires the following raw material, approximately:

Fig. 63.—View of a Modern Paper-Machine Room.

TABLE VIII.

	Tons.	cwt.	qrs.	lb.
Mechanical pulp	70	0	0	0
Sulphite pulp	30	0	0	0
China-clay	9	0	0	0
Alum	1	15	0	0
Rosin	0	15	0	0
Alkali	0	5	0	0
	111	15	0	0

The paper so obtained is a soft-sized news suitable for dry printing. There appears to be a loss of 12 tons in manufacture, but the greater part of this is due to the fact that the newspaper when first turned out only contains about 5 per cent. of atmospheric or natural moisture, whereas air-dry pulp is usually reckoned as containing 10 per cent. of natural moisture.

The following facts relating to the production of a cheap daily newspaper are of interest:

TABLE IX.

Circulation assumed at 200,000 copies daily.

Weight of a single copy assumed at one-fifth of a pound.

Total weight of 200,000 copies about . .	18 tons.
Material required:	
Mechanical pulp	$13\frac{1}{2}$ tons.
Sulphite pulp	$4\frac{1}{2}$ tons.
China clay	$1\frac{1}{2}$ tons.
Chemicals, &c., for sizing . .	$\frac{1}{4}$ ton.
Coal for motive power, &c. . .	18 tons.
Water evaporated for steam . .	32,000 gals.
Water used for manufacture . .	100,000 gals.
Wood required for pulp:	
For mechanical pulp . . .	16 cords.
For sulphite pulp	9 cords.
Total	25 cords

A cord of logs for pulp is a pile of logs 4 feet wide, 4 feet high, and 8 feet long (128 cubic feet). For 25 cords the number of trees to be cut down is 200 (having an average height of 50 feet and an average diameter measured 5 feet from the ground, of 8 to 9 inches.)

CHAPTER VII

PACKING PAPERS

Browns—Shop papers—Millboards—Vulcanised board—Pulp boards.

THE manufacture of this class of paper forms an important section of the paper trade, since a great variety of material is necessary to meet the special needs of many industries. The extremes are well represented by the very thin tissue browns used for dressmakers' patterns on the one hand, and the thick strong brown papers used for wrapping heavy hardware goods on the other. The gradual

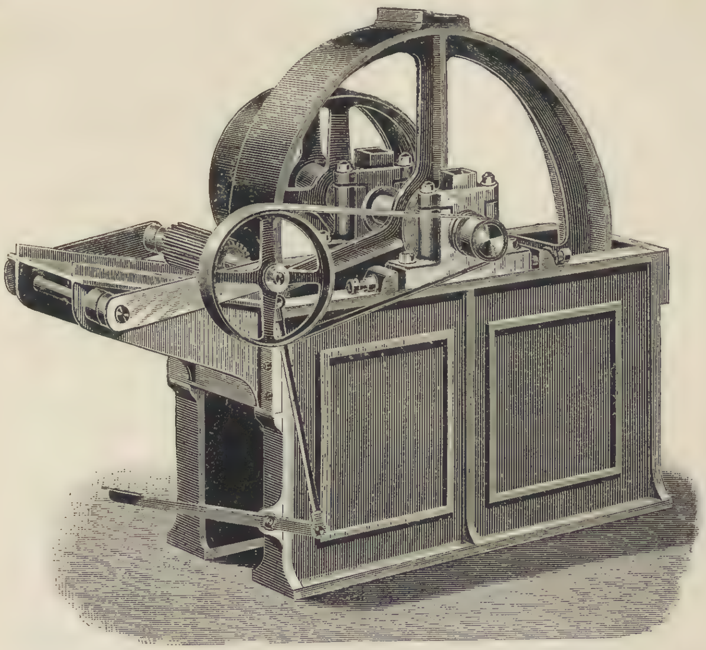


Fig. 64.—Rope-chopper.

substitution of boxes for brown paper in the packing of goods is also responsible for the development of a special branch of the trade.

Strong Browns.—These papers are manufactured from such raw materials as soda wood pulp, hemp, old rope, gunny, hemp and jute scutchings, waste paper, and all kinds of waste fibrous material.

The strongest papers which exhibit remarkable resistance to wear and tear are produced from old hemp ropes or from high-class soda wood pulp, while the

poor qualities contain a good deal of mechanical pulp and common waste papers.

The treatment to which the old rope, after first being chopped up, is subjected consists of a short boiling with caustic soda in revolving boilers for four to six hours at a pressure of about 20 to 25 lbs. The boiling is only carried out to the extent necessary to produce a fairly complete isolation of the filaments and fibres without reducing them to the condition of pure cellulose. The boiled pulp is then submitted to the usual washing and beating operations, the process of bleaching being omitted. The sizing, colouring, and finishing are conducted in the ordinary way, no special process being necessary.

With brown papers prepared from soda wood pulp the process of manufacture is practically identical with that used for ordinary printings, so that little need be said as to the manufacture of these papers.

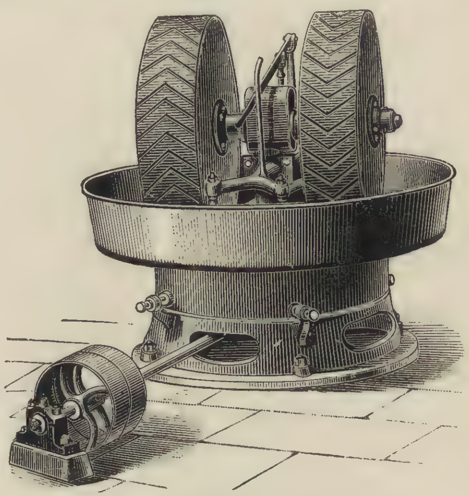


Fig. 65.—Edge-runner or Kollergang.

Medium Browns. — These papers are made from jute refuse, gunny, and waste papers used by themselves or mixed in varying proportions. Old jute bags and similar goods are first cut up by means of an ordinary rag-cutter and then boiled in a spherical or cylindrical digester for four to six hours at a pressure of 25 to 30 lbs. with a small proportion of caustic soda, the fibre being subjected to a comparatively mild treatment.

Waste papers are handled in several ways, being softened and pulped in large tanks, in edge-runners, or in special pulping-machines, such as Wurster's kneader or Cornett's breaker.

Common Browns.—The cheapest qualities of wrapping paper are made by blending old waste papers, mechanical wood pulp, and any other fibrous material which by a stretch of the imagination can be called paper.

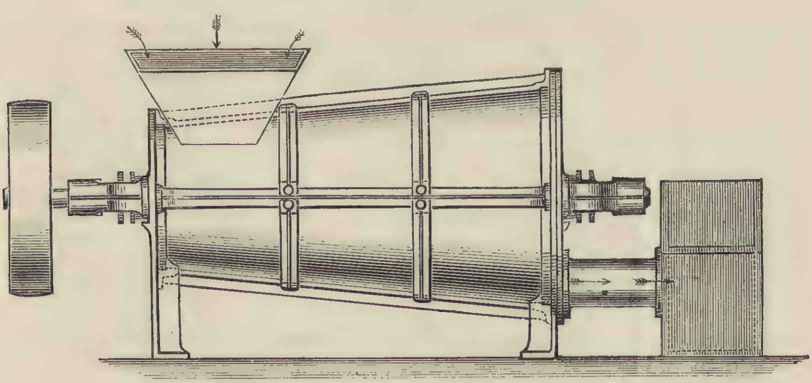


Fig. 66.—Cornett Breaker for disintegrating Waste Papers and Wood Pulp.

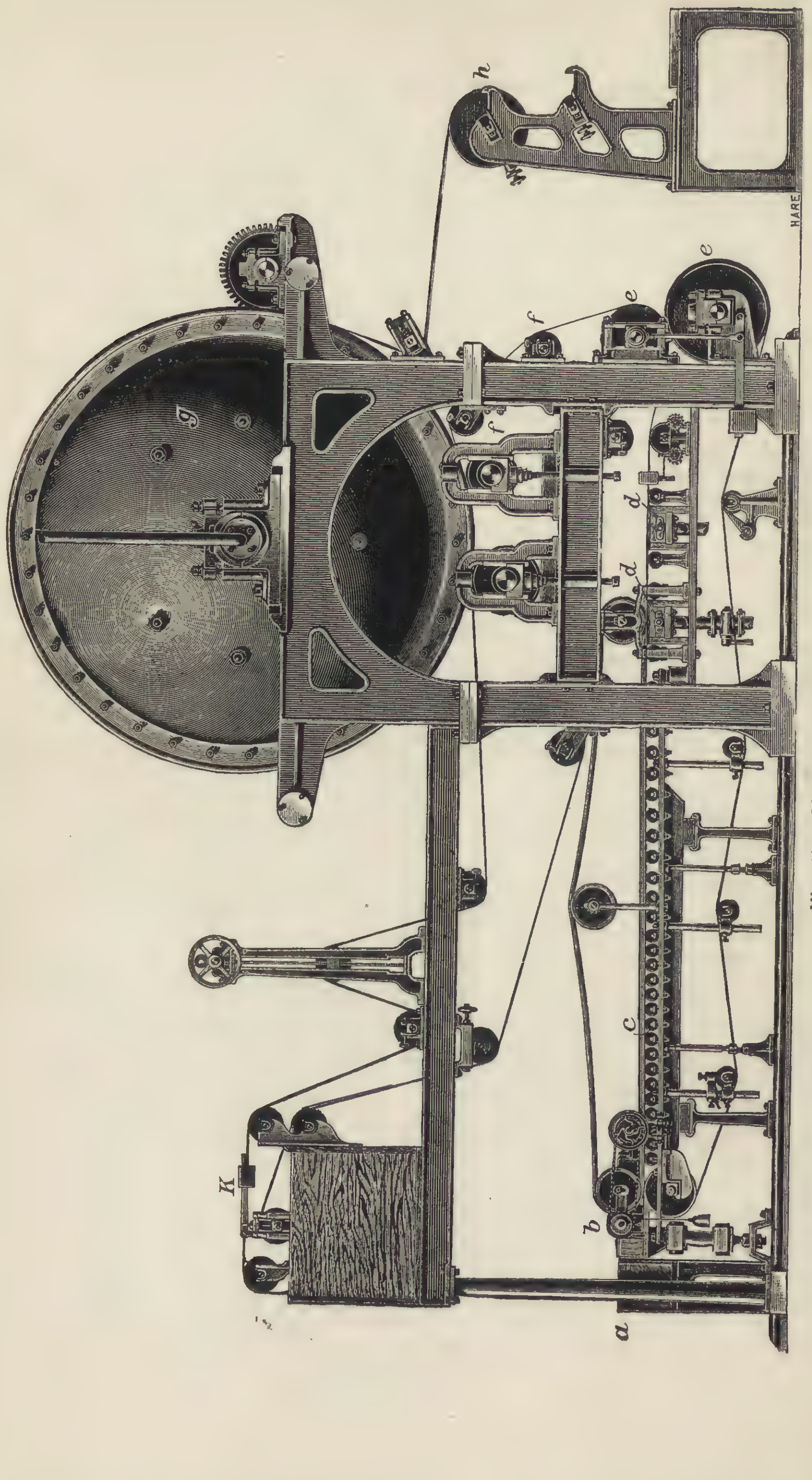


Fig. 67.—Single-cylinder Paper-making Machine.

M.G. Caps.—A large number of thin papers used by the bakery and confectionery trades, the drapery and dry-goods trades are generally known as M.G. papers. These two letters signify that the papers are machine-glazed, and usually on one side only. The majority of the papers are manufactured from hard sulphite wood pulp, possessing great strength, the colour being of secondary importance. The preliminary operations in the manufacture of the paper are of the usual order, but the paper-machine is of peculiar construction, being known as the single-cylinder, or Yankee machine.

The wet end of the machine resembles the ordinary Fourdrinier in having the usual strainers, endless wire, and couch-rolls. The wet web of paper is transferred from the couch-roll on to an endless felt, which carries the paper over one large drying-cylinder, 10 to 12 feet in diameter, which is placed on a tall framework over the wet end of the machine. The outside of the cylinder is well

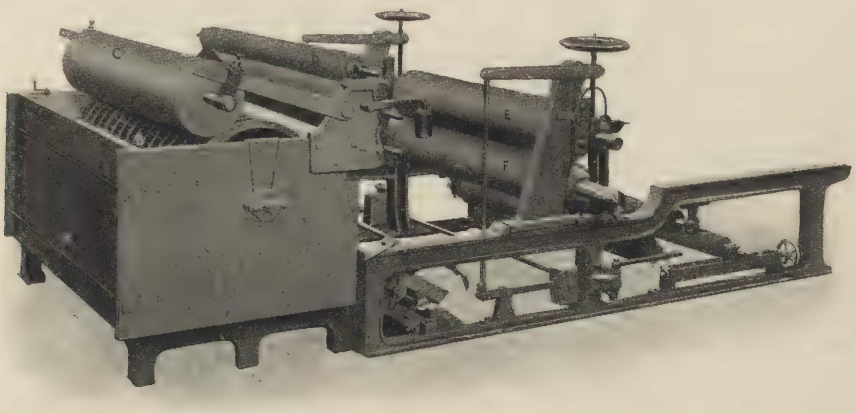


Fig. 68.—Millboard-making Machine.

A. Vat containing pulp and water.
B. Hollow cylindrical drum.
C. Felt covered roll.
D. Squeezing rolls.
E. Drum upon which millboard is rolled.
F. Felt-carrying roll.
G. Felt-washing roll.

polished, so that the surface of the paper which comes into immediate contact with it becomes highly glazed. This machine is specially adapted for such thin papers as M.G. Caps, biscuit papers, tissues, and the like.

Single Cylinder Paper-machine.—The pulp flows from a stuff-chest through the strainer *a* into the distributing box *b*, and on to the endless wire *c*. The excess water is removed by the usual suction-boxes *dd*, and the wet sheet of paper then passes through the couch-rolls *ee*, over the guide-rolls *ff*, round the drying cylinder *g*, and is finally reeled up at *h*. The felt carrying the wet paper from the couch-rolls to the drying-cylinder passes through a washing-trough *k*, which removes dirt and small fibre. (Fig. 67.)

Millboard.—The manufacture of boards for boxes is a simple operation carried out by means of the board machine, which is practically identical with the wet-press machine used in making sheets of mechanical pulp.

The raw material used consists of old waste papers mixed occasionally with boiled gunny. The papers are soaked in hot water, broken up, mixed with any other material selected, and beaten for a short time to ensure thorough

incorporation, after which the mixture diluted with the required quantity of water is discharged into stuff-chests.

The pulp flows from the stuff-chest into the reservoir A of the board machine, in which revolves a large hollow wire-covered cylindrical drum B. The water with which the pulp is mixed passes through the wire into the interior of the drum, and flows away by means of an overflow pipe fixed at the centre of the drum (not shown in the drawing) on the outside of the reservoir. The pulp adheres to the outer surface of the drum and comes into contact, as the drum revolves, with an endless felt passing round the roll C. The wet sheet adheres to the felt, and is carried by it over the guide-roll D, and between the couch-rolls E F. The sheet of pulp winds itself continuously round the upper roll E, while the felt passes round the lower roll F under the machine, between the guide-rolls G, back to the roll C. (Fig. 68.)

The thin sheet being wound continuously on the couch-roll E, is gradually formed into one thick sheet. The thickness of the board is determined by the number of revolutions made by the roll E. A bell is attached to the frame of the machine near the shaft of the roll E, and as soon as the sheet is the required

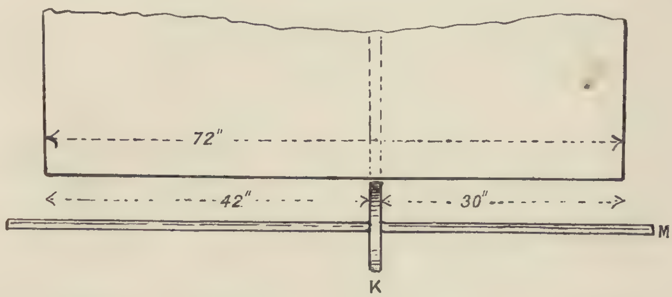


Fig. 69.—Diagram to illustrate method of slitting thick pulp boards on the Board Machine.

thickness the bell rings, and the men in attendance at once remove the sheet without stopping the machine, an operation which is easily effected.

The machine shown in Fig. 68 is constructed to make a sheet of given width, determined by the width of the couch-roll E, and of given length, determined by the diameter of the roll E. Thus a couch-roll 72 inches long and 14 inches diameter will give a sheet 72 inches by 44 inches.

If the distance between the couch-rolls and the reservoir is increased, an additional appliance may be used by means of which the full width of 72 inches can be automatically cut up into two or more smaller sizes. This consists, as shown in Fig. 69, of a small circular disc K fixed on a shaft M stretching across the machine from one side to the other. The edge of the disc is about half an inch wide. The felt carries the thin sheet of pulp from the guide-roll C past the disc, which revolves in contact with the felt, and a thin strip of pulp adheres to the edge of the disc, so that the sheet is divided into two smaller sheets. The pulp attached to the disc is washed off by a continuous stream of water. The position of the disc K on the shaft M can be varied so as to cut the sheet as required. The diagram illustrates the position necessary for cutting the sheet of 72 inches into 42 inches and 30 inches respectively.

The wet boards removed from the machine are piled up, with pieces of coarse sacking between them, and subjected to great pressure, in order to remove the excess of water and at the same time to "close up" the sheet and produce a

hard solid board. The pressed boards are then dried either by simple exposure to air for the production of what are known as air-dried boards, or by exposure to a current of heated air passing through a closed chamber. After drying, the boards are glazed by heavy calender-rolls.

Vulcanised Boards.—The heavy dense material known as vulcanised board is prepared by soaking damp boards or sheets of paper in strong solutions of zinc chloride. Two or three thicknesses of board or paper are treated in this way, placed together and passed through heavy rollers, which squeeze out the excess of solution and press the thin boards into a compact mass which, when dried and glazed, is exceedingly hard.

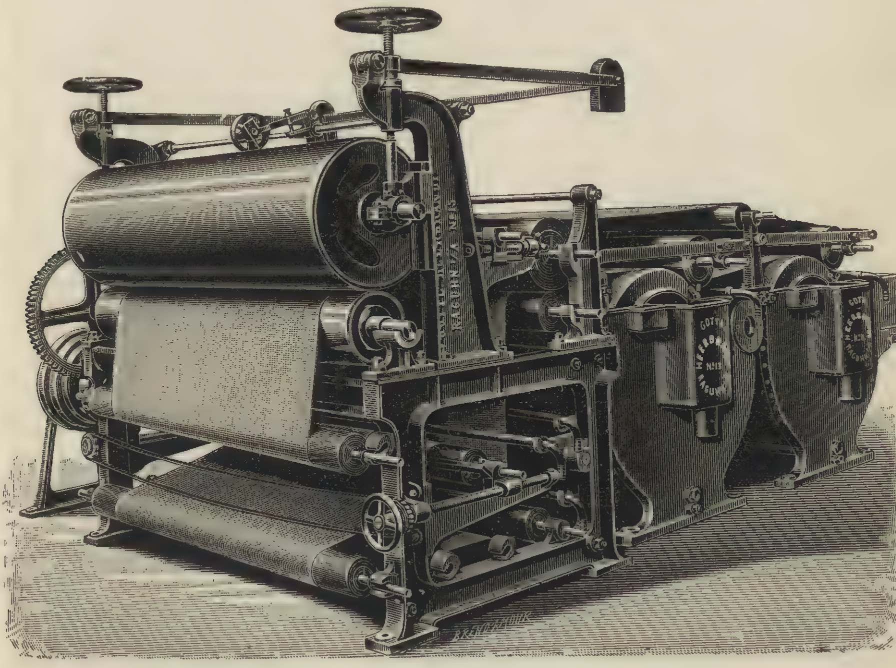


Fig. 70.—Double-cylinder Board Machine for thick boards.

Panel Boards and Roofing.—A cheap waterproof board is made by soaking boards in a hot mixture of rosin and tallow. Paper barrels are rendered hard and waterproof by this means.

Middles and Thin Boards.—Thin cards and cheap middles are now produced in very large quantities on the continuous board machine, which resembles an ordinary Fourdrinier paper-machine in every respect, except as to the endless wire. Instead of the wire, two or three cylinder moulds are used, and the sheets of wet pulp are brought into close contact, carried through heavy press-rolls which cause the two or three sheets to combine into one compact mass, and then dried over heated cylinders in the usual manner.

Wood-pulp Boards.—These are manufactured on the board machines of the intermittent type, or on continuous machines, according to the bulk and weight required.

CHAPTER VIII

"ART" PAPERS

Process of manufacture—Materials used—Qualities of Art paper—Defects in Art paper—Influence of mineral constituents—Surface—Printing process.

Process of Manufacture.—These special papers are now made in large quantities to supply the demand for a paper having a smooth surface suitable for the printing of half-tone blocks. The clearness of detail, and the sharpness of outline required in an illustration produced by process printing cannot be obtained on ordinary paper, however highly glazed and finished, since the surface is not sufficiently smooth, but by the application of a mineral coating an enamelled surface is obtained which is perfectly even and level, and capable of taking an extremely high polish. The machinery employed in the production of these papers is not complicated, and the operation appears to be quite simple, though, as a matter of fact, the difficulties connected with the manufacture and use of "Art" papers are numerous.

Fig. 71.—Section of Art Paper coated one side only, showing coating matter on surface. (J. Christie.)

The coating applied to the surface of the paper varies in composition according to the quality of the work, the mixture consisting of some inert mineral substance, such as china-clay, blanc fixe, or enamel, mixed with the proper quantity of an adhesive such as glue or casein. For high-class papers in which good colour and extra finish are the desired qualities, blanc fixe and satin white are used in conjunction with glue, commoner qualities being coated with china-clay.

The machine for the manufacture of coated paper consists of three parts. The first is the coating section proper, the second is the drying apparatus, and the third the appliance for reeling up the paper. (Fig. 72.)

The reel of paper to be coated is placed in any convenient manner upon a shaft at the back of the coating apparatus, which is a large drum about 4 feet diameter, and 4 feet wide. The paper is led round under the drum and then over the top, and as it passes over it is brought into close contact with a short endless felt, which transfers the enamel mixture to the paper. The mixture is continuously fed into a narrow copper trough fixed to the front of the machine, and this is maintained at a suitable temperature. A copper roll rotating in the

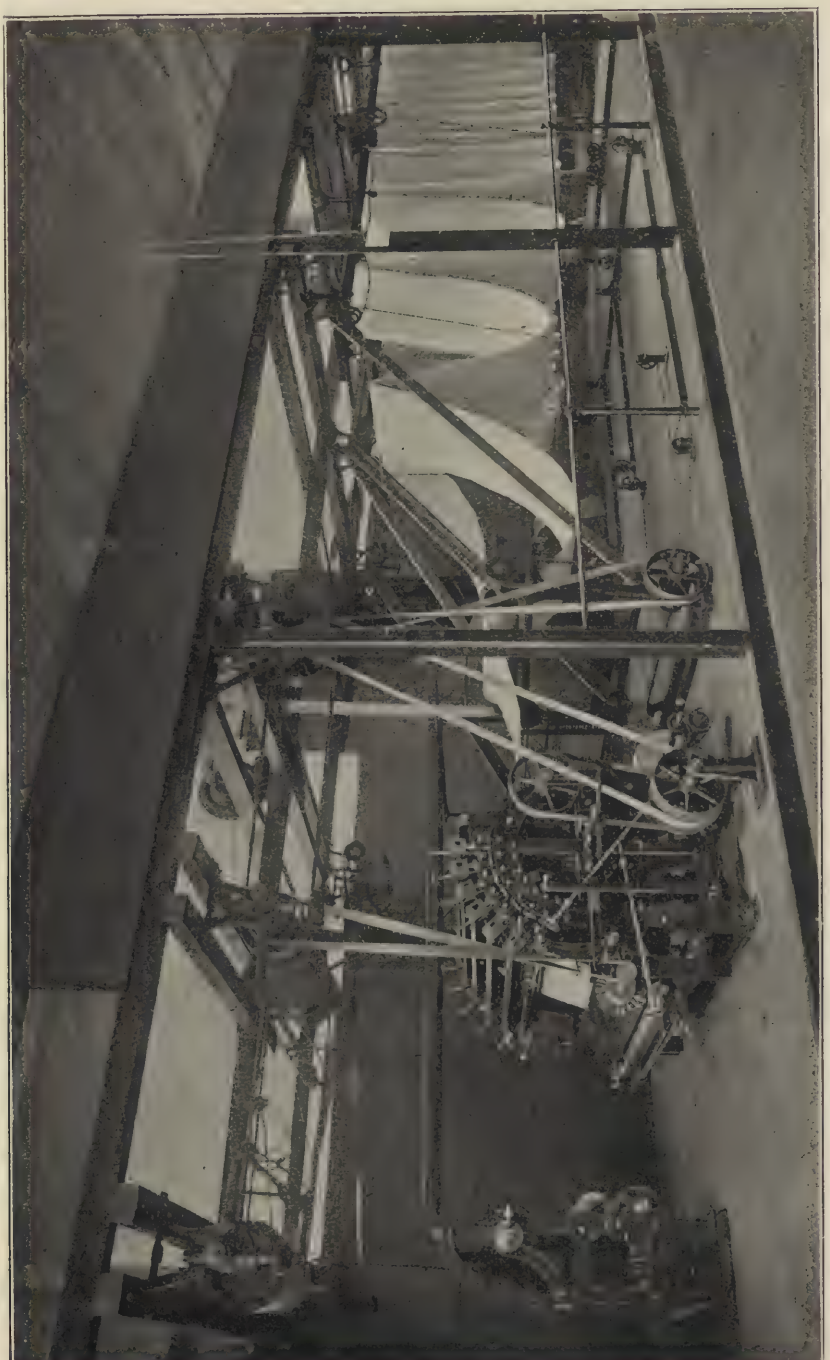


Fig 72.—General View of a "Coating" Plant.

A. Coating machine. B. Drying apparatus. C. Reeler.

trough brings up a steady stream of the liquid on to the felt, and the amount of coating transferred to the paper is regulated by squeezing-rolls. The thorough adhesion of the enamel and its even distribution over the surface of the paper is brought about by a series of brushes, usually seven in number, which operate on the top of the drum and brush the enamel well into the paper. Some of these brushes are fixed, while the others, actuated by small cranks, move regularly from side to side. The last two or three brushes are fitted with soft bristles to ensure an even surface free from "brush marks." The wet coated paper is then drawn over to the drying apparatus, which consists of two long parallel rails fixed 8 or 9 feet above the floor, upon which slowly travel endless chains carrying a series of sticks at regular intervals. By an ingenious device the wet paper is caught on the sticks, taken up a sloping incline until it reaches the rails, and then it falls into a series of festoons or loops, the whole of which are moved bodily forward upon the rails. The drying is hastened by the use of a current of air heated to about 85° Fahr. If the room is not long enough, a turn-table is provided which causes the festoons to describe a semi-circle at the end of the room, bringing the paper along a second set of rails back to any required distance. This device has the additional advantage of bringing the finished paper directly under the observation of the man in charge of the coating machine. The dried paper is reeled up by a special reeling appliance.

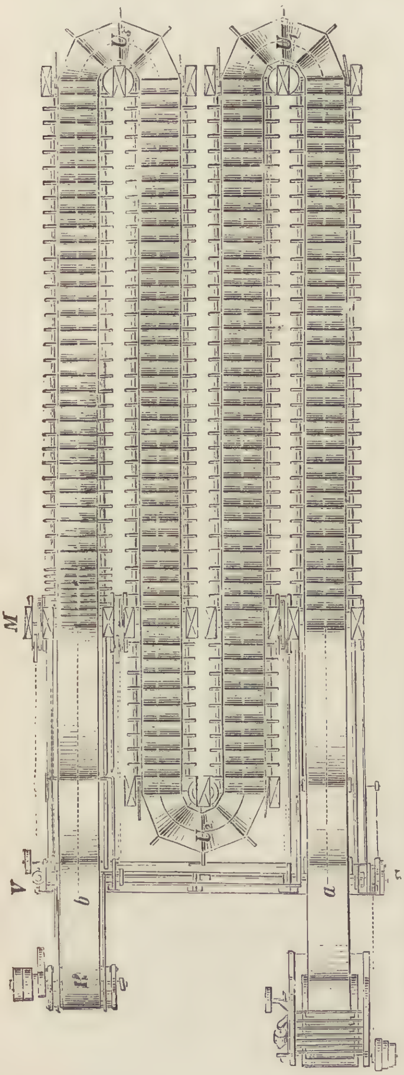


Fig. 73.—Plan of Coating Machine, showing Coating Apparatus, Drying Machinery and Reeler.

The opposite side of the paper is coated in a similar manner, the reel from the first operation being passed through the machine a second time.

Machines have recently been introduced for coating both sides of the paper at one operation, but the results are not altogether satisfactory for high-class work.

When coated the paper has a dull surface, and a high finish is then given to it by means of the supercalender, after which process the paper is cut to any required shape and dimensions.

Materials Used.—For ordinary art papers the proportions of enamel and glue are 100 lbs. of mineral to 18 to 25 lbs. of glue. These substances are mixed

with water to give a solution of 10 gallons. The glue is soaked in cold water for 24 hours, and then gently heated in a copper steam-jacketed pan while the mineral is worked up into a creamy paste with water and thoroughly mixed with the glue. Aniline dyes are added to the mixture for the production of coloured or tinted papers.

Of recent years casein has been largely employed as a substitute for glue. About 18 to 20 lbs. of casein are required for 100 lbs. of mineral, and, since it is insoluble in water, borax or ammonia is necessary as a solvent. The casein is stirred into cold water and gently heated to about 100° Fahr., and after the addition

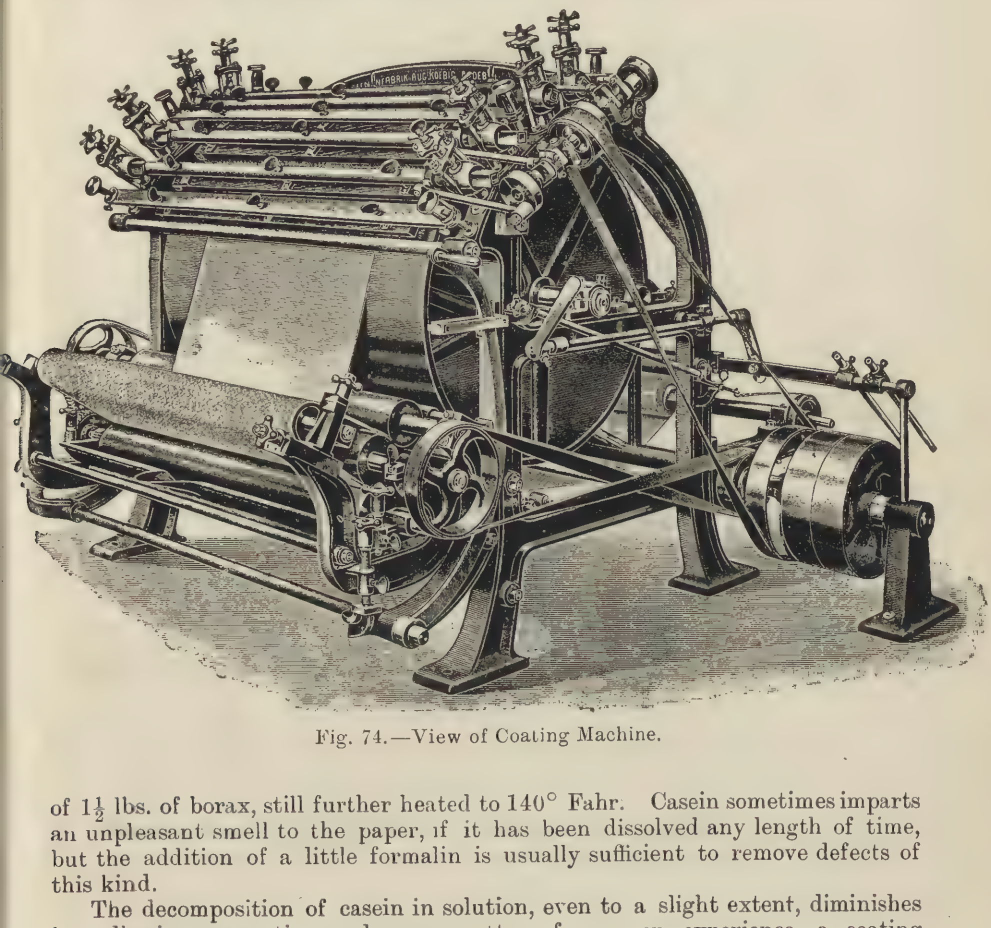


Fig. 74.—View of Coating Machine.

of 1½ lbs. of borax, still further heated to 140° Fahr. Casein sometimes imparts an unpleasant smell to the paper, if it has been dissolved any length of time, but the addition of a little formalin is usually sufficient to remove defects of this kind.

The decomposition of casein in solution, even to a slight extent, diminishes its adhesive properties, and as a matter of common experience, a coating mixture prepared from casein which stands over from a Saturday to the Monday following is frequently rendered foul and useless. Inattention to details of this kind is a fruitful source of trouble, which only appears at the printing office when it is then impossible to trace the primary offender. The manufacturers of art papers are frequently puzzled to explain defects for which there does not appear to be any adequate cause, and this question of the alteration of adhesive properties in the prepared coating mixture is one of them. The alteration may be traced in some instances to comparatively simple causes.

Thus when ordinary glue and moist satin white are the ingredients for a mixing, it is evident that the ratio of dry glue to dry mineral can only remain constant when the raw materials are of uniform and constant composition. If the moist enamel contains a lower percentage of water than some accepted standard, then the amount of glue must be varied to meet it. But the manufacturer does not always test the mixture, and variations may frequently arise without any apparent cause.

The explanation of the differences, which may occur with the printing on successive deliveries of art paper to the printer from the paper-maker, may appear almost too simple, but it is a matter of common experience to the consulting chemist, that simple causes are those which come to be frequently overlooked by manufacturers. It is only specific instances of this kind that indicate the possibility of arriving at a satisfactory solution of the difficulties encountered in every commercial industry.

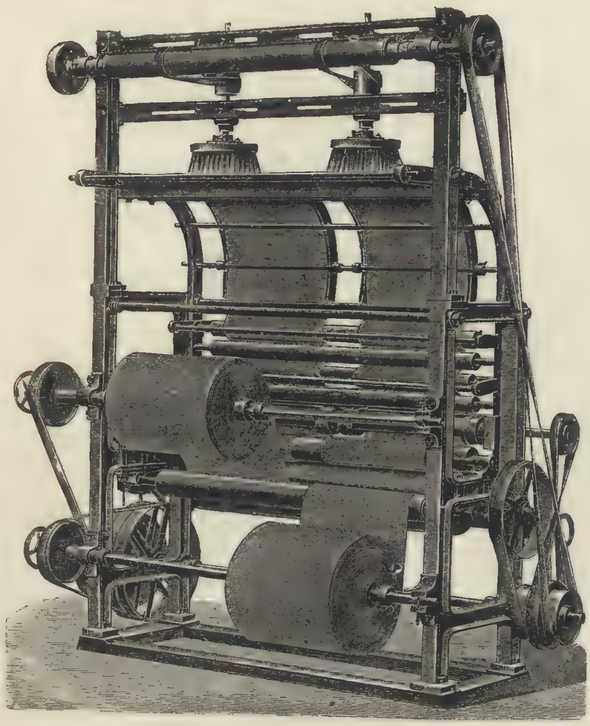


Fig. 75.—Machine for reeling up the Coated Paper after drying.

Qualities of Art Paper. — The finished art paper presents many physical qualities different from those found in the body paper. The weight and bulk are greatly increased by the additional mineral matter added, the increase being determined by the amount of finish necessary. For heavy art papers the extra weight is generally 10 to 12 lbs. per ream of 480 sheets, and the thickness is increased 12 to 15 per cent., so that books made from such papers are very heavy to handle, and are also extremely bulky.

The unpleasantness and fatigue caused by the reflection of light from the surface of high-glazed art papers is a matter of common experience, and the use of art paper for ordinary letterpress work cannot be too strongly condemned. The use of poor paper, closely printed letterpress, unsuitable surface, outrageous colours, and other defects in relation to paper generally, are fruitful sources of injury to the eyes and brains of readers, perhaps more so than most people are aware. A close investigation into this subject would amply repay attention.

The "Body" Paper.—It is clear from these descriptions of the methods used for coating paper, and the reasons given for the necessity of such a coating in the production of a purely artificial surface, that the composition and quality of the "body" paper is not a matter of very great importance. To a large

extent this is quite true, but in the better qualities of art papers the nature of the "body" must be studied. Flexibility and resistance to the frequent turning over of the leaves of a book can only be ensured by the use of suitable material as the constituent of the body paper. Esparto is found to be pre-eminently suitable for the purpose, and when mixed with chemical wood pulp in varying proportions gives results which are satisfactory.

With cheap art papers, the materials used for the "body" are of greatly inferior quality, and mechanical wood pulp often forms a large proportion of the paper. In the entire absence of any standards of quality, it is not surprising to find that many high-class illustrations of considerable beauty, even if only of a temporary character, are printed on very poor paper.

It is necessary that the body paper should be carefully made, its surface being fairly even, yet not too smooth. The marks of the machine wire should not be too pronounced, since irregularities on the surface of the paper due to these marks cannot be completely obliterated if the coating subsequently put on the paper is thin.

Another important feature in the body paper is the extent of the sizing. The papers are treated with rosin size, and the conditions for proper coating require a uniformly sized body paper in order that the ratio of glue to enamel on the surface may remain constant.

Defects in "Art" Paper.—The irregularity in printing results may sometimes be traced to uneven sizing of the body paper, so that during the coating operation, the glue of the coating mixture tends to soak more readily into the body paper at one time than another, thereby disturbing the composition of the artificial surface.

In cases where the ratio of glue to enamel is already barely sufficient to resist the pulling or lifting power of the printer's ink, any slight alteration of this kind may give rise to serious trouble.

It must not be forgotten that there are many conditions which affect the final results. The influences may be cumulative, or, on the other hand, they may neutralise one another, so that the figures which analysis may give as representing the percentages of certain ingredients cannot always afford conclusive evidence. The following is an illustration of a simple case of "cumulative influences." A coating mixture of definite composition, which experience has proved to be suitable for a given paper, may be applied to a soft-sized body paper. The paper, after coating, may be insufficiently calendered. The ink used for printing may be a trifle more tacky or tenacious than usual. All these conditions tend to lower the resistant power of the coating, and the printing results will be poor owing to what may be termed for want of a better phrase "cumulative influences."

The chief quality in a coated paper is a good surface, which must be hard enough to resist any tendency to "lift" and yet soft enough to allow the ink to be absorbed sufficiently without spreading in order that the defect of "setting off" may be avoided.

The hardness of surface depends on the proportion of glue in the mineral coating. If the amount is too small then the enamel comes away from the paper and adheres to the process block so that the picture is spoilt. This is technically known as "lifting." If, however, the amount of glue is too great, the ink is not absorbed quickly and it comes off on to the back of the next sheet of paper leaving the printing machine. This "setting off" is a serious drawback to rapid printing, in which the production of 1500 copies per hour is by no means an uncommon occurrence.

In colour work the presence of too much glue is also a defect since the colour will not lie flat and the effect produced is very poor. A good surface gives a

deep flat colour, but a surface which is too hard gives a mottled, washy and unsatisfactory result.

Fig. 76.—Photo showing effect of printing with Art Papers containing varying percentages of Glue.

It may be noted that the supercalendering of a paper has something to do with the hardness of the surface. The main object of the polishing is to finally smooth down any slight irregularities on the paper, and to give a surface that will reproduce every detail in the block with accuracy. A little extra rolling to sheets which show a tendency to "lift" will sometimes improve the surface sufficiently for the work because the glazing slightly increases the power of the coating to resist the ink. The resistance so obtained is only momentary, but before the coating has time to become detached, the pressure of the block against the paper is removed, and the desired result is obtained.

The importance of these two factors, one of which is chemical, represented by the glue, and the other a purely mechanical one, namely, the glazing or supercalendering, may be judged by a careful comparison of pictures printed on "art" papers containing varying proportions of glue and varying degrees of surface.

Fig. 77.—Effect of printing with a Half-tone Block on a Hand-made Paper.

The conditions shown in Fig. 76 are those of extreme cases, created in order to bring out clearly the influence of the adhesive matter. Naturally the paper-maker endeavours to obtain a good coating with a minimum quantity of glue, but slight variations in the direction of using less glue from a standard which experience has proved suitable for a certain class of work are found to be risky. In consequence of this, the surface of a paper coated

for use with light half-tone blocks may pick off when employed with blocks giving heavy dark shades. The production of a dense black print is always a severe test on an art paper.

Influence of Mineral Matter on Printing Results.—In a hand-made paper containing little or no mineral matter, the picture is blurred and indistinct, the depression of the water-mark being brought into prominence by the absence of ink along the lines of the mark itself. (*See* Fig. 77.)

In a cheap printing paper with a small proportion of 5 to 10 per cent. of loading, there is a slight improvement in the result.

Fig. 78.—Effect of printing with a Half-tone Block on "Art" Paper.

With a machine-finished paper containing about 16 to 18 per cent. of loading or mineral matter a marked improvement is obtained.

With an imitation art paper containing about 30 per cent. of mineral matter, much of which lies on the surface of the sheet, the picture shows more detail.

Finally, in the art paper having surfaces composed entirely of mineral matter, the clearness of the picture leaves nothing to be desired. (Fig. 78.) But it must not be overlooked that the surface is artificial and the paper itself plays quite a secondary part, being sandwiched in, as it were, between two layers of mineral coating. In consequence of this the quality of the "body" paper is often considered a matter of no importance, and many art papers are merely composed of ingredients in which the conditions essential for durability are chiefly remarkable for their absence.

The rationale of the process is therefore perfectly clear. In a normal high-class writing paper, the absence of any mineral matter absolutely precludes an

even surface, and the glazing or polishing of these surfaces as produced by processes perfectly familiar to the papermaker, viz., the use of the supercalender, the plate-glazing rolls, and so on, is not sufficient to give the desired effect. Consequently, the print is blurred, indistinct, and lacking in detail, and the curious outlining of the water-mark is a clear indication of unevenness of surface. The examination of the surface of a high-class linen paper reveals the existence

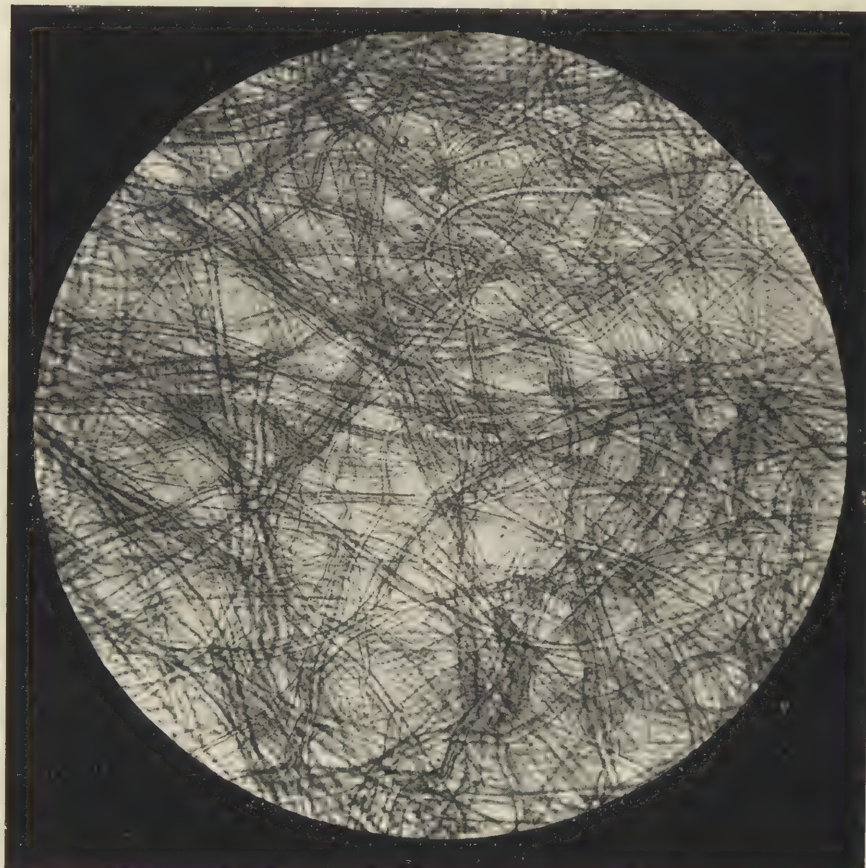


Fig. 79.—Surface of O.W. Linen Paper. × 90. (Photo by J. Christie.)

of numerous fibres crossing and recrossing one another in every conceivable direction. It is obvious that since even minute fibres occupy a certain volume, the surface of the paper at all such points of intersection must be slightly above the spaces between them, and that no amount of pressure will bring them into one common plane. (Fig. 79.)

Now the addition of a small amount of mineral matter tends to fill up the interstices of the paper. The particles of mineral matter, such as china-clay, which is the usual loading for cheap papers, distribute themselves around the fibres and fill up, more or less, the air spaces, and thus reduce the irregularity of

surface. The pressure due to the action of the rolls in the supercalender reduces the minute undulations on the surface of the sheet just as in the case of a high-class rag paper, but the interstices are not so pronounced. As the percentage of mineral matter is increased the improvement in the paper judged from the printing standpoint is noticeable, and apparently the particular characteristic necessary in an "art" paper is only to be obtained by a complete

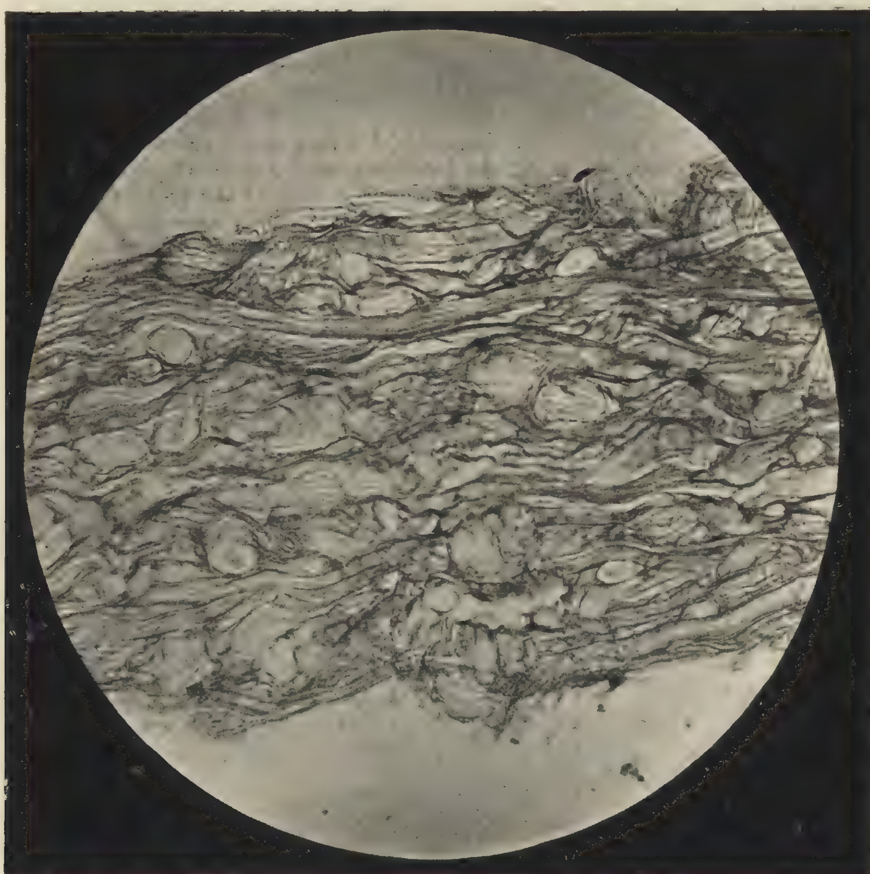


Fig. 80.—O.W. Linen Paper (Transverse) Section. × 325. (Photo by J. Christie.)

degradation of the actual paper by a mineral substance which has nothing in common with the fibrous constituents.

The "imitation art" paper, which is a compromise between an ordinary cheap printing paper and the so-called high-class "art paper," contains a very high percentage of mineral matter which is brought up to the surface by a peculiar process of treatment, so that the sheet of paper is rendered more suitable for half-tone printing. To use the word "paper" in connection with a sheet which consists of 35 per cent. china-clay held together by a few low-class vegetable fibres is an abuse of terms, but it is one which has some commercial significance.

Suggestions as to Surface.—With such a purely artificial surface upon a sheet of paper, which can easily be removed by friction with the moistened finger, it is evident that durability of the pictures is scarcely to be expected.

The resistance of the art paper to the ravages of time is a matter which should not be difficult to determine, since all the elements for rapid deprecation are present in the shape of a large percentage of a cheap glue mixed with a common clay lying on the surface of a more or less inferior body paper, so that the moisture and damp of an ordinary atmosphere find books of this class an easy prey in course of time. The preservation of books containing the fine art illustrations obtained by process printing can be prolonged by careful storage in a properly dried room, and having regard to the large number of expensively prepared books which are being continually published, this question is of the utmost importance.

In this case, as in many similar instances, the rule that "prevention is better than cure" holds good, but so far, the introduction of a fine art paper in which the smoothness of surface shall be an inherent quality of the actual paper, and not a mere artificial characteristic, has not been successfully accomplished.

There is a big field open for a systematic research into this question, which would afford considerable scope for chemical and mechanical ingenuity. No doubt the discovery of some method for obtaining a smooth surface without the employment of such adventitious substances as those which obtain at present would be extremely profitable to the inventor. Attempts have been made to obtain a coating by means of some form of dissolved cellulose, but so far without success. Investigation should probably proceed along the lines of the "Willesden process." In the manufacture of waterproof Willesden paper and similar goods, the body paper is passed through a bath containing cellulose dissolved in Schweitzer's reagent, an ammoniacal solution of cupric oxide. When this solution evaporates, a greenish mass of cellulose and copper oxide coats the whole surface, and the coating becomes intimately associated with the body paper by reason of the partial dissolution of the surface of the paper which takes place as the ammonia evaporates.

The colour of the final product is greenish, but the substitution of the copper by zinc brought about by treating the Schweitzer's reagent with metallic zinc, produces a colourless solution of the corresponding zinc salt, which has somewhat similar properties.

Other soluble forms of cellulose offer considerable attractions for research in this new field. The work of Messrs. Cross and Bevan, with the thiocarbonates and acetates of cellulose, is well known in this connection, but the application of these soluble derivatives as a coating pure and simple has not yet met with any wide measure of success.

The attempt to produce a glossy surface on paper by the reprecipitation of a soluble cellulose seems to be a correct and scientific procedure, eliminating to a large extent the conditions which favour disintegration and the disunion of three irreconcilable elements, the body paper, the mineral coating and the printers' ink.

Many of the difficulties experienced by printers using art papers may be overcome by careful attention to the conditions of working. The most important condition for successful work is that of an equable temperature. It is a matter of common experience that printing with art papers on Monday gives far more trouble than the work later on in the week, and that in the winter this difficulty is more pronounced. The general principle to be observed is the desirability of having the art paper, the ink and printing presses all at the same temperature, not only during the process of printing, but also for some time before use. The regulation of the heat of the room to some fixed standard would do away with

many troubles which are at present ascribed to the "paper" in some vague manner. Thus, for example, a given sample of ink may give satisfactory results one week because the supply has been kept in the printing-room, while the next week, being brought direct from a cold store room, it may give rise to endless trouble.

With regard to the ink which is used for printing on art paper, no systematic work has been done, and it is evident that a proper investigation into this question would result in some definite information. As the enamel on the art paper in its natural condition has a dull surface the ink must be of good quality. In general terms, the ink should have sufficient consistency to be tacky, the

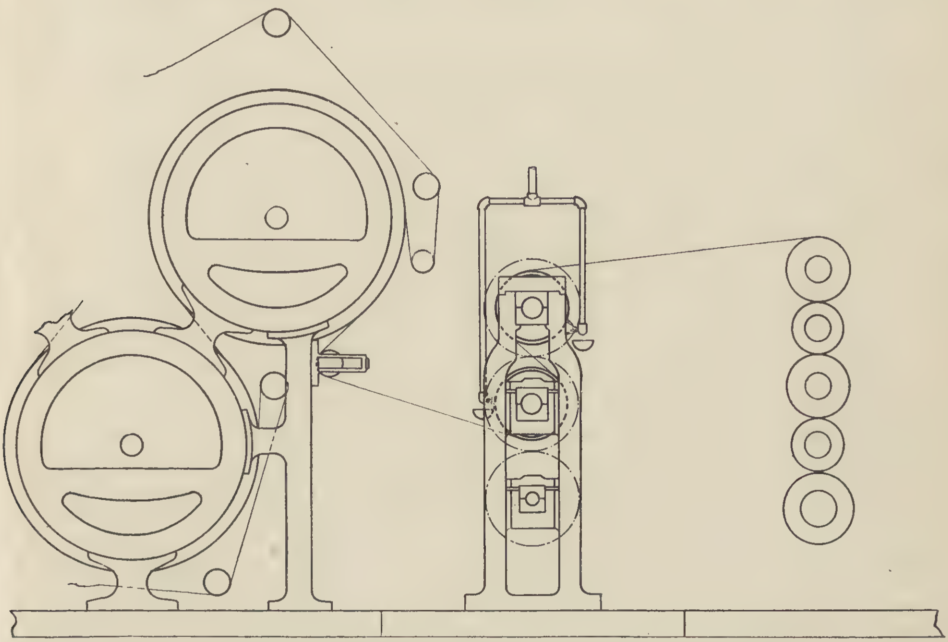


Fig. 81.—Damping-rolls used for putting a "Water-finish" on Papers.

rollers should be hard and well seasoned, with a proper distribution of the ink by the inkers. In addition to the property of consistency, the ink should be manufactured in such a way as to dry quickly when placed on the surface of the paper. The consistency is determined by grinding down the colouring-matter with as much strong varnish as possible, the ink being thinned down if necessary afterwards, though the addition of too much medium varnish for this purpose tends to make the ink when dry flake away from the surface of the paper. The addition of driers is not always essential as the constituents of the ink pigment possess in themselves the necessary qualities for this purpose. Considerable technical knowledge is necessary in the task of making up ink varnish to the required consistency and with the required tackiness and drying properties, because so many factors enter into consideration, many of which are of a mechanical nature, as already intimated.

Probably, just as important a factor is the nature of the paper itself. Successful printing can only be accomplished by practical experiment, and this

seems to lie in the hands of the printers as much as in that of the ink manufacturer or paper-maker.

Imitation art paper is largely used for catalogues and cheaper printings where clearness of detail is not so essential as in the best art papers. It is a very efficient substitute in many respects, but it lacks strength and durability. It is usually made by adding large quantities of china-clay to a mixture of wood pulp and esparto, and producing a heavy loaded paper in which only a small proportion of rosin size is used. The paper is made on the machine in the ordinary way, and treated as it passes on to the calenders of the machine by means of the water doctor. This is a device which causes the surface of the paper to come into contact with water just before it is drawn through the rolls of the calender. The somewhat bulky sheet wetted superficially in this manner is suddenly compressed by the pressure of the rolls and flattened down so that the surface has the appearance of a coating. The proportion of clay in an imitation art paper is often as great as 35 per cent., and this, coupled with the "soft sizing," is the cause of the somewhat limp feel and handle of this class of paper. It is, however, produced cheaply and answers its purpose. (Fig. 81.)

Duplex coated papers may be produced by colouring a suitable coating-mixture with an aniline dye for one side, and colouring a second coating-mixture for the other side of the paper.

The Printing Process.—The production of a half-tone block from any photograph or picture is an interesting process, which may be described very briefly here. The picture is mounted on a board in front of a camera and brilliantly illuminated by means of two powerful arc lights placed on either side, and a photograph of the picture taken in the ordinary way except that a screen grating is put in front of the sensitive plate.

The screen grating is an important feature of the process, and is prepared in the following manner: A sheet of plate glass of good quality is coated with an asphalt varnish. Lines are ruled diagonally at forty-five degrees across the varnished surface by an automatic ruling-machine, which is capable of ruling parallel lines up to any degree of fineness. The number of lines per inch depends on the work for which the screen is to be used. For coarse, rapid work such as newspaper printing the lines are 50 to an inch; for book illustrations, the lines are 170–200 to an inch. The lines are etched on the glass by means of hydrofluoric acid, which eats away the glass along the lines ruled by the machine. A white enamel is rubbed into the etched lines, baked in by heat, and the glass carefully polished. Two such glasses placed together with the lines crossing at right angles are cemented with Canada Balsam to form a screen grating.

The effect produced by the interposition of such screen grating is to give a picture formed entirely of a very large number of small dots, shadows being represented by the closeness of the dots, and the lighter tones by dots of various sizes. The gradation of the light and shade depends greatly on the experience and skill of the operator in adjusting the screen at a correct distance.

The *screen negative* is developed in the usual way and used for the production of a print on a copper plate. The plate is carefully washed and coated with a sensitive solution, made by mixing fish glue, albumen, bichromate of ammonia, and dilute chromic acid in certain proportions. The plate, brought into contact with the screen negative, is exposed to an arc light, for a period of six to eight minutes, and then thoroughly washed in order to remove all the portions of the coating not rendered insoluble by the light.

The washed plate is then immersed in a bath of some aniline dye, usually methyl violet, which stains the picture and renders all the detail clear and distinct. When dry the plate is enamelled by the heat of a Bunsen flame, the colour of the picture changing from blue to grey, and finally to a deep brown

tone. When this point is reached the plate is cooled down, and the coating resembles a hard enamel.

The "etching" process requires a good deal of skill and technical experience, as well as a knowledge of artistic effect. The process is a simple one, consisting in the immersion of the plate, the back of which has been previously coated with black varnish, in a bath of weak nitric acid; the dots being protected by the enamel remain intact, while the spaces between are eaten out by the acid.

From this plate a rough proof is taken, which affords the operator the opportunity of determining how much further the etching process must be taken, and the extent to which it may be necessary to etch some portion of the plate deeper than others in order to give good results in the final picture. The finished block is mounted on a slip of wood, and in that condition is ready for the printer.

CHAPTER IX

THE PHYSICAL QUALITIES OF PAPER

Weight and substance—Thickness—Bulk—Strength—Elasticity—Resistance to crumpling and folding—Sizing qualities—Absorptive capacity—Imperviousness—Transparency—Colour and finish—Surface and other qualities.

Weight and Substance.—These qualities of paper are usually expressed in terms of the weight of a ream of 480, 500, or 516 sheets, as the case may be. For high-class papers the ream usually contains 480 sheets, while with common printings 500 or 516 sheets go to the ream. The methods for determining the weight of the ream are very simple.

(1) The sheet of paper is cut to a given size, and weighed on some form of special paper-scales which indicate without further calculation the weight of a ream, such as Leunig's scales. (Fig. 82.)

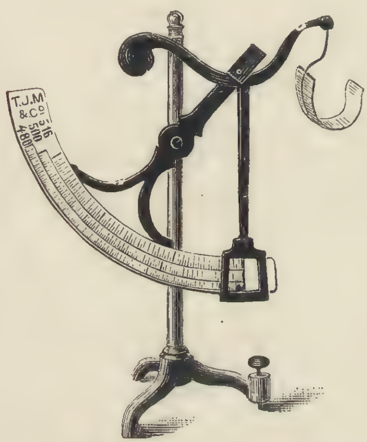


Fig. 82.—Leunig's Paper-scales.

Example.—A sheet measuring 20″ by 30″ placed in the pan of the Leunig's scales indicates the weight of a ream as follows:

480 sheets = 35·0 lbs.
500 sheets = 36·4 lbs.
516 sheets = 37·5 lbs.

(2) The sheet cut to the full size can be weighed on an ordinary letter balance, and the weight of the ream calculated therefrom. If the scales are not very sensitive it is advisable to weigh five or ten sheets in order to minimise any error in weighing. This is especially necessary in the case of thin papers.

Example.—Found the weight of two sheets of tissue paper, which measured 20″ × 30″ to be $\frac{1}{2}$ oz. A ream of 480 sheets weighs $\frac{1}{2}$ by 240, or 120 ozs., that is $7\frac{1}{2}$ lbs.

(3) If the piece of paper is not full size, then it is necessary to cut a piece to some convenient size, and calculate the weight of a full-sized sheet and subsequently the weight of the ream. A specially sensitive form of paper-scales has been constructed by Leunig, which indicates the weight of a ream of demy ($17\frac{1}{2}$″ by $22\frac{1}{2}$″) by means of a piece of the paper cut to a standard size of 4 inches square.

Example.—A sheet measuring 4″ by 4″ when placed on Leunig's demy scales may indicate a weight per ream of 56 lbs.

(4) A slip of paper cut to any convenient size can be weighed on a fairly sensitive balance, and the weight of the ream calculated.

Example.—An odd piece of paper cut to the size 5 inches by 10, weighs 70 grains. From this it follows that a sheet measuring 20 inches by 30 would weigh 840 grains, and a ream 480 times the weight of a single full-sized sheet, that is $57\frac{1}{2}$ lbs.

(5) In some cases the piece of paper available is exceedingly small, but the method of determining the substance is exactly the same, the only precaution necessary being the employment of a very sensitive balance. If the weighing of a small piece is not carried out carefully a serious error will be introduced.

Example.—A piece of paper cut to a size measuring 1 inch square weighs $\frac{1}{2}$ grain. Hence, weight of a ream of 480 sheets double crown (20 inches by 30), is :

$\frac{1}{2} \times 20 \times 30 \times 480$ grains
or 144,000 grains, that is 20·6 lbs.

Since 7000 grains equal 1 lb. the weight of the ream is 20·6 lbs., that is to say, just over $20\frac{1}{2}$ lbs. The necessity for using a sensitive balance is obvious from the fact that the weight of the small piece is multiplied by 288,000.

A special form of Leunig's scale sensitive to pieces 2 inches by 1 may also be used for this purpose. (Fig. 83.)

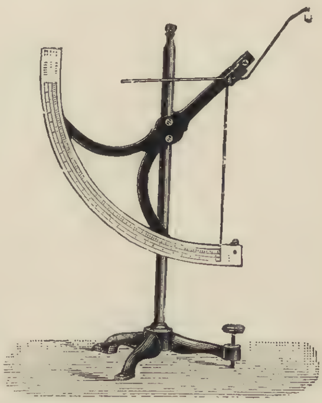


Fig. 83. Sensitive Paper-scales for small Samples.

Equivalent Weights.—The equivalent weights of paper are readily determined by the simple rules of proportion, although it is more customary to ascertain the weight of paper in any standard size for some other standard size by reference to published tables. For unusual dimensions the equivalent weight must be calculated.

Example.—A sheet 17″ by 25″ weighs 20 lbs. per ream (480 sheets). What is the equivalent weight for a sheet 51″ by 20″?

$$\text{Since } 17 \times 25 \times 480 \text{ square inches} = 20 \text{ lbs.}$$
$$\text{Then } 51 \times 20 \times 480 \text{ square inches} = 20 \times \frac{51 \times 20 \times 480}{17 \times 25 \times 480}$$
$$\text{or equivalent weight} = 48 \text{ lbs.}$$

The "Rule of Three" can be applied to all questions relating to the weight of paper.

Equivalent weights are in direct proportion to the areas of the single sheets, and this fact can be expressed in the shape of a formula capable of general application.

Let W represent the weight of a ream of paper.
A ,, ,, area of a sheet in the ream.
w ,, ,, weight of another ream of paper.
a ,, ,, area of a sheet in the second ream.

Then the relation is $\frac{W}{w} = \frac{A}{a}$

In its extended form $A = (L \times B)$ and $a = (l \times b)$ where L, B, and l, b, are the lengths and breadths of the respective sheets.

$$\text{Then } \frac{W}{w} = \frac{A}{a} = \frac{L \times B}{l \times b}$$

Various problems can be solved by means of this simple formula, of which several examples are appended.

Example.—What is the equivalent weight of a ream 34″ by 45″ weighing 40 lbs. for a paper 68″ by 54″.

In this case W = 40. A = 34″ by 45″. a = 68″ by 54″

$$\frac{W}{w} = \frac{A}{a}. \quad \frac{40}{w} = \frac{34 \times 45}{68 \times 54}.$$

From this, w = 96 lbs.

Example.—A ream of paper 36″ by 29″ weighing $14\frac{1}{2}$ lbs., being damaged, is cut down to 36″ by 27.″ What is the weight afterwards?

A ream of sheets 36″ by 29″ weighs $14\frac{1}{2}$ lbs.

A ream of sheets 36″ by 27″ weighs

$$\frac{14\frac{1}{2} \times 36 \times 27}{36 \times 29} = 13\tfrac{1}{2} \text{ lbs.}$$

Example.—A reel of paper is 80 inches wide, the paper having a substance of 20″ by 30″ = 56 lbs. The paper is re-reeled and slit into two smaller reels 50 inches and 30 inches respectively. What are the relative weights of the reams in the reels?

On the full-sized reel, before slitting, a complete sheet measures 80″ × 30″.

Hence w = 4 × 56 = 224 lbs. (for a ream of 80″ × 30″).

On one reel the sheet measures 50″ × 30.″

$$\frac{W}{w} = \frac{A}{a}. \quad \frac{56}{w} = \frac{20 \times 30}{50 \times 30}.$$

Hence w = 140 lbs. (for a ream of 50″ × 30″).

On the second reel, the sheet measures 30″ × 30.″

$$\frac{W}{w} = \frac{A}{a}. \quad \frac{56}{w} = \frac{20 \times 30}{30 \times 30}.$$

Hence w = 84 lbs. (for a ream of 30″ × 30″).

In all the reels the paper has the substance 20″ × 30″ = 56 lbs.

Example.—A ream of paper $19\frac{1}{4}$ inches by $26\frac{1}{2}$ weighs 44 lbs. If the equivalent weight of another ream is 35 lbs., the sheet being $25\frac{1}{2}$ long, what is the width of the sheet?

$$\frac{W}{w} = \frac{L \times B}{l \times b} = \frac{44}{35} = \frac{19\frac{1}{4} \times 26\frac{1}{2}}{25\frac{1}{2} \times b}.$$

Hence b = 16 inches nearly.

Thickness and Bulk.—(1) The bulk of a paper may be expressed in terms of the thickness of a single sheet or the thickness of a ream. If the ream of paper is available its thickness may be determined at once by direct measurement with a rule, or by means of ordinary callipers.

(2) The thickness of a single sheet of paper may be measured by means of a micrometer gauge, the construction of which may be seen from Fig. 84. With the cheaper forms of this instrument it is difficult to obtain very accurate or uniform readings on account of the absence of any method for regulating the pressure exerted on the sheet of paper. This error can be avoided by the use of a gauge fitted with a small friction coupling which slides round on the micrometer screw directly the pressure reaches a fixed maximum, so that any further movement of the screw is prevented.

Still more elaborate appliances are available in which the sheet of paper is brought between two horizontal surfaces, the upper one being connected to a dial which registers the distance between the two plates and thus measures the thickness of the paper.

(3) Schopper's gauge is a convenient apparatus which registers upon a dial the exact thickness of a single sheet in thousandths of an inch or in millimetres. (Fig. 85.)

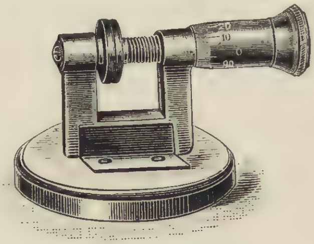


Fig. 84.—Gauge for measuring the Thickness of Paper.

(4) One convenient form of micrometer which will be appreciated is Ciceri Smith's patent micrometer, which has several commendable features. (Fig. 85A.) The measurements are automatically recorded by an index which operates like a cyclometer, so that the thickness can be read off easily. The pressure on the paper is always uniform, as the instrument is constructed so that directly the pressure reaches a certain fixed amount the spindle ceases to advance when the head is turned. These are obvious advantages in any instrument for measuring the thickness of paper.

Fig. 85.—Dial Gauge for measuring the Thickness of Paper.

(5) In the absence of any special apparatus the paper must be folded over several times and the thickness determined with a pair of small callipers and a fine scale showing an inch divided into fiftieths, or one-hundredths.

The thickness of the paper is an important element when the question of the bulk is considered in reference to the binding of books. The errors of measurement should not exceed 5 or 6 per cent. The bulk of a number of sheets required for a book ought to be over-estimated rather than under-estimated, as it is easier to compress the papers slightly to fit the cover than to correct the mistake of using a cover which has been made too large through under-estimation.

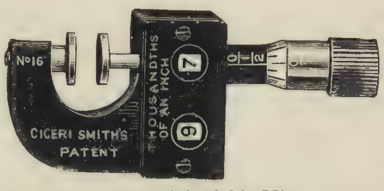


FIG. 85A.—Ciceri Smith's Micrometer.

TABLE X.

Examples.

Method of measurement.	Number of sheets measured.	Thickness one sheet, inches.	Thickness of ream, inch s.
Ream measured by a rule	480		3·00
Callipers on 10 folds	10	·006	2·88
Micrometer gauge	5	·0062	2·97

Strength.—The strength of a paper may be recorded in several ways. It may be measured in terms of the weight required to break a strip of given width and length, or in terms of the pressure required to fracture a sheet fixed

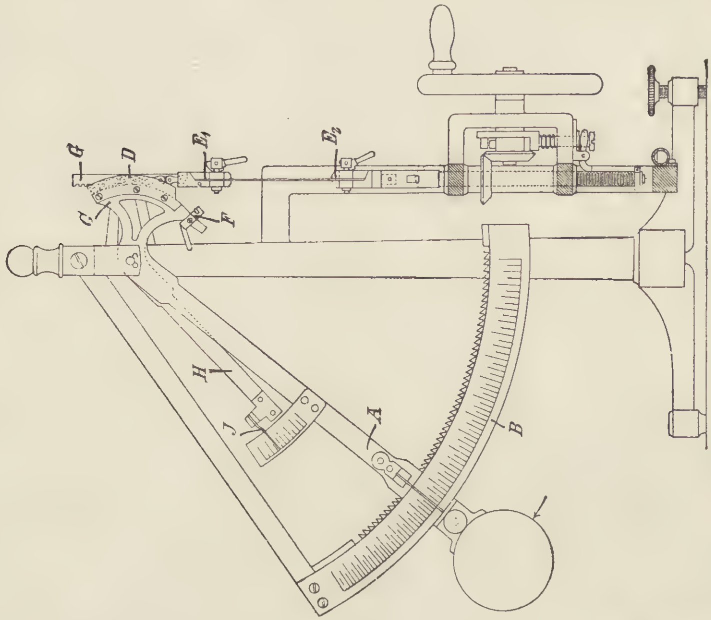


Fig. 87.—Schopper's Paper-tester. Section.

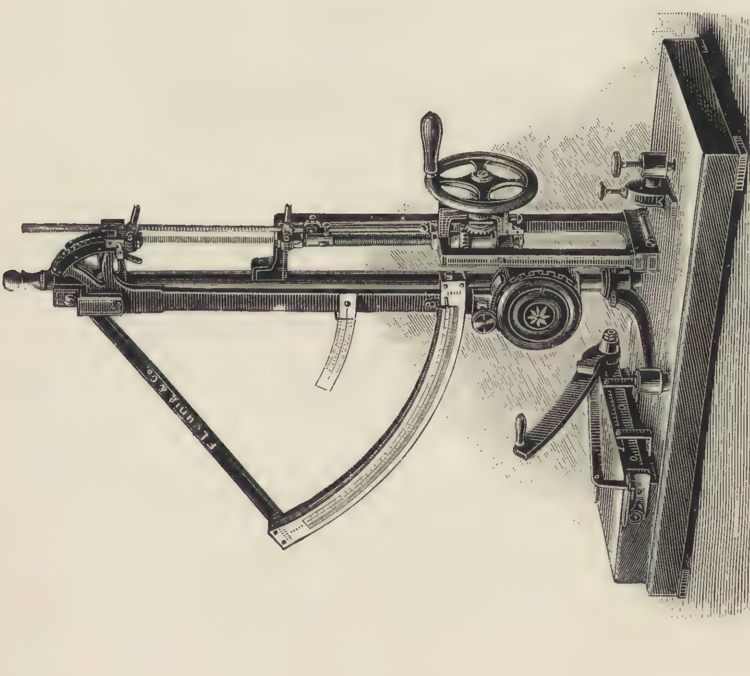


Fig. 86.—Schopper's Paper-tester.

horizontally between two suitable clamps the former being regarded as the *breaking strain* and the latter as the *bursting strain.*

Of the machines which register the breaking strain by means of tension applied to the strip of paper held vertically, or horizontally, between two clamps there are several well-known types.

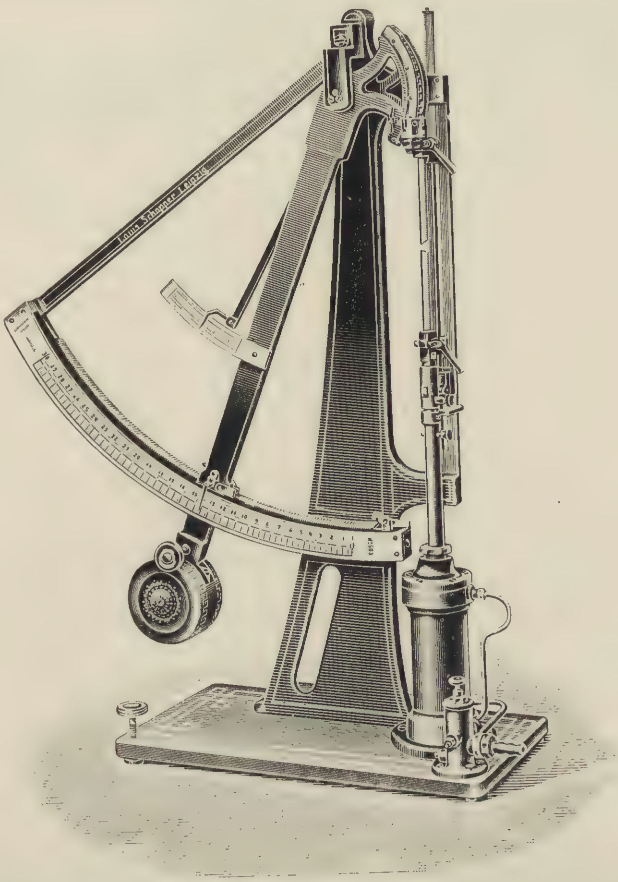


Fig. 87A.—Improved form of Schopper's Paper-testing Machine in which the paper is stretched by hydraulic power instead of a hand wheel.

The Schopper machine.—This is the recognised standard machine which has been devised to meet the requirements of the Government paper-testing institutes in Germany. The strip of paper cut to a definite width of 15 millimetres (five-eighths of an inch) and a length of 180 millimetres (seven inches) is fixed vertically between two clamps and submitted to tension, which is produced by the movement of a heavy weight actuated at a uniform rate. The instrument also records the amount of elongation which the paper undergoes before it breaks. When the paper breaks the pointers remain stationary so that the readings of breaking strain and elongation can be noted.

The operation of the machine (*see* Fig. 87) is as follows: The strip of paper cut to the proper length and width is inserted between two clamps E_1 E_2. When

the handle is turned the clamp E_2 is drawn slowly downwards, and this movement causes the lever A to move gradually outwards along the segment B by means

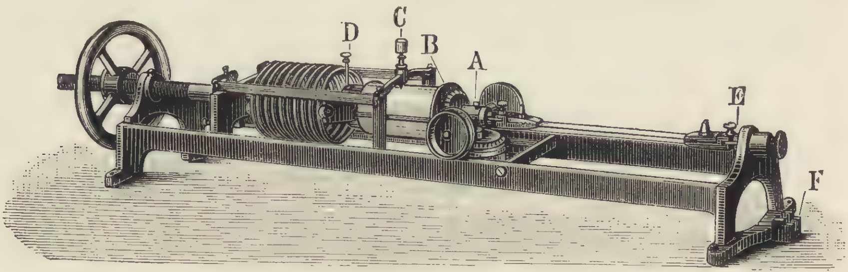


Fig. 88.—Leuner's Paper-testing Machine.

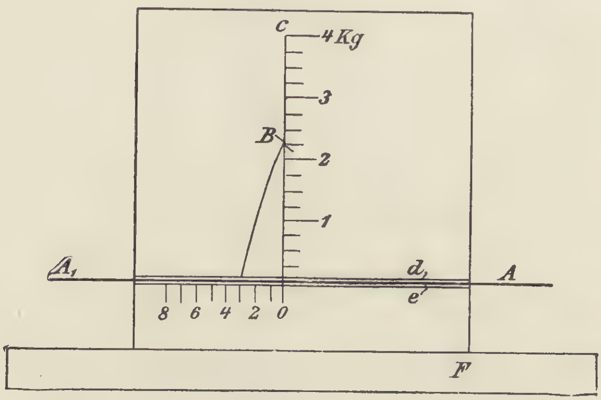


Fig. 89.—Diagram of Curve registered automatically on Leuner's Paper-tester.

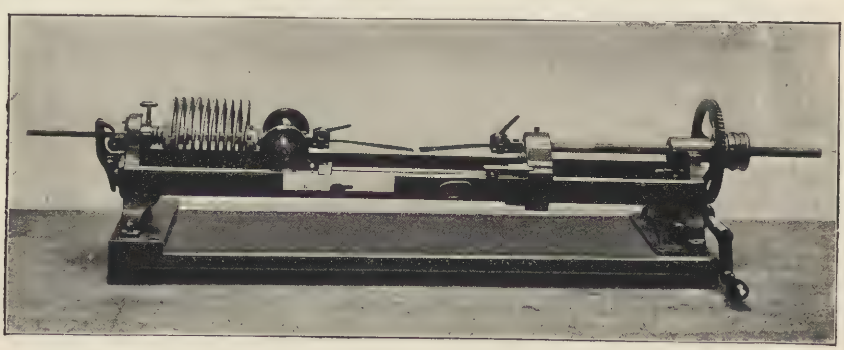


Fig. 90.—Wendler's Paper-testing Apparatus.

of a rack work G, which operates on the small segment C attached to the upper end of the lever. When the paper breaks the lever A remains stationary, being held in position by lugs which drop into small notches cut on the segment B.

The stretch of the paper while under tension is registered by means of a

lever *H*, the indicator of which measures the stretch on a small segment attached to tho lever *A*.

The Leuner machine.—The paper cut to a standard size of 15 millimetres wide and 180 millimetres long, is inserted horizontally between two clamps. The tension is applied through a spiral spring actuated by a hand wheel or by means of a small water motor. The breaking weight and elongation are automatically registered on a piece of squared paper. (Fig. 88.)

The Wendler machine.—This is a convenient apparatus in which the tension is produced by means of a spiral spring, and the elongation measured by a slide and pointer.

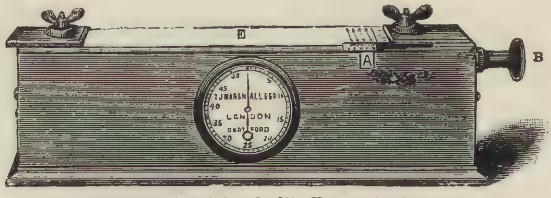


Fig. 91.—Marshall's Paper-tester.

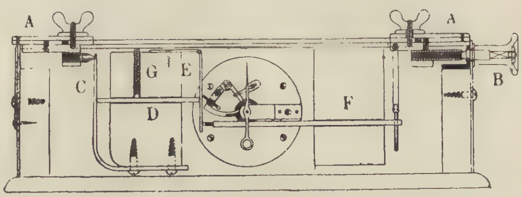


Fig. 92.—Section of Marshall's Paper-tester.

This machine is simple in construction, the paper being stretched horizontally between two clamps. By the movement of the handle one clamp is drawn back and the tension applied to the strip by means of the spiral spring attached to the second clamp.

The Marshall machine.—This finds considerable favour in England because it is a cheap, portable and convenient apparatus. The width and length of the strip can be varied, and this is a special feature of the machine, which proves very useful for certain investigations. The elongation of the paper under tension can be measured.

The paper which is to be tested is fastened between the two clips AA. As soon as the screw B is turned to the right, a pressure is put on the spring C (through the straining of the paper), which is connected with the spindle D, the joint E and the segment which gears into the pinion, working the hand, and registers the breaking strain in pounds on the dial.

The spiral spring G serves as a stop for the spindle D, so that it stops exactly on the spot to which the pressure on the spring C has brought it.

By turning the screw B to the left, the hand moves back to zero (the starting-point). The plate A indicates the stretch of the paper.

The Carrington machine.—One of the early forms of paper-testing machines. The width of the strip can be varied from $\frac{1}{2}$ inch to 2 inches. It is used by H.M. Stationery Office for testing brown papers. (Fig. 93.)

The Jackson machine.—This has been introduced for testing strips up to 4 inches in width. It is simple in construction, consisting of an ordinary spring balance mounted on a stand, and provided with clamps for the paper. (Fig. 94.)

In testing paper for the breaking strain, several interesting questions arise.

(1) *The necessity of selecting some standard length for the test strip.*—It is clear that the selection of a short strip tends to give a high reading, while a long strip may be expected to give a low reading. For example, a strip 12 inches long will give a lower result than the average of four tests on strips each 3 inches long. If the 12-inch piece breaks at 16 lbs., the strength of the paper is taken

as 16 lbs.; but if the piece had been cut up into four strips, only one of them would break at 16 lbs., the others breaking at higher figures, say 17, 18, and 18 for example This would give an average of $17\frac{1}{2}$ lbs.

Fig. 93.—The Carrington Paper-tester.

Fig. 94.—Jackson's Paper-tester.

The following experimental result serves to illustrate this point:

A brown paper of good quality, substance 29 lbs. double crown, was examined, various lengths of constant width ($\frac{1}{2}$ inch) being tested. Table XI. gives the figures for each length, five tests being made in each case.

TABLE XI.

Length of strip.	Breaking strain (mean of five tests).
2 inches	6·90 lbs.
4 ,,	6·85 ,,
6 ,,	6·67 ,,
8 ,,	6·60 ,,
10 ,,	6·30 ,,
12 ,,	5·80 ,,

(2) *The necessity of having a definite width for the test piece.*—Theoretically width should have no influence on the breaking strain, since a 2-inch strip might be expected to stand double the breaking strain of a 1-inch strip. As a matter of common experience, it frequently happens that the wider strips favour a higher result. The following tests show the variations of an actual case:

Examined a common printing, 28 lb. double crown, testing strips of varying width on a constant length of 3 inches (between the clamps). Each figure recorded is the mean of five tests.

TABLE XII.

Width of strip.	Breaking strain (calculated to a standard width of 1 inch).
0·25 inch .	9·40 lbs.
0·50 ,,	13·60 ,,
0·75 ,,	14·56 ,,
1·00 ,,	16·10 ,,
1·25 inches	16·36 ,,
1·50 ,,	16·57 ,,
1·75 ,,	16·50 ,,
2·00 ,,	16·57 ,,

(3) *The influence of the conditions under which the tension is applied to the paper.*—Usually the tension is applied at a constant rate, the speed of the machine being carefully regulated as far as possible. This method, however, takes no account of the variation in stretch exhibited by papers or by the same paper in the two directions of the sheet. Very little investigation has been made as to the proper conditions for the rate of application of the tension in the case of paper. If one paper has twice the percentage stretch of another, and both are tested in a machine in which the rate of speed is constant, then the former would take a longer time to break. The exact effect of varying times ought to be thoroughly investigated.

(4) *Influence of moisture in the air.*—The moisture of the air has considerable effect upon the strength and elasticity of a paper. As the proportion of moisture in the air increases, so the strength decreases, and the stretch of the paper under tension increases. This question has been very fully studied by Herzberg, who gives the results of an interesting investigation with a good writing paper made of rags, sized with rosin, and tested under varying conditions of moisture. (*See* Table XIII.)

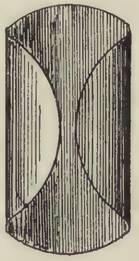


Fig. 95.—Determination of the Machine Direction of Papers.

Machine direction of paper.—The strength of paper is never absolutely the same in both directions of the sheet, even in the best hand-made papers. With machine-made papers the difference is usually very marked, the strength being greatest in what is known as the *machine* direction—that is, the direction in which the wet pulp is travelling on the wire during its formation into paper. When the sheet of paper under examination is a normal sample, so that it may be assumed the edges are cut strictly parallel to the machine direction, as is usually the case, the two directions are readily identified by the differences in the tests for strength. If the sample is irregular in shape, without any folds, and the directions cannot be determined by a close examination of the appearance of the sheet when held up to the light, the machine direction may be detected by floating a circular disc on water for a few seconds. The paper

TABLE XIII.

Relative Humidity of the Air.	Moisture contained in the Paper.	Breaking Weight.			Elasticity.			Breaking Length (Kilometres).		
		Machine direction.	Cross direction.	Mean.	Machine direction.	Cross direction.	Mean.	Machine direction.	Cross direction.	Mean.
Per cent.	Per cent.	Kilos.	Kilos.	Kilos.	Per cent.	Per cent.	Per cent.	Km.	Km.	Km.
100	21·5	3·07	2·59	2·83	8·9	14·1	11·5	2·41	2·03	2·22
90	13·5	4·89	3·67	4·28	9·8	14·4	12·1	3·83	2·88	3·36
80	8·9	7·41	5·21	6·31	10·2	13·7	12·0	5·75	4·06	4·91
70	8·4	8·64	6·20	7·42	8·9	12·1	10·5	6·77	4·83	5·80
60	6·5	9·24	6·42	7·83	8·1	9·9	9·0	7·20	5·00	6·10
50	5·6	9·86	6·80	8·33	6·6	7·6	7·1	7·68	5·32	6·50
40	3·4	10·18	6·78	8·48	4·0	4·0	4·0	7·93	5·31	6·62
30	2·3	9·60	6·82	8·21	2·9	3·1	3·0	7·45	5·31	6·38

is carefully removed so that the upper surface is not wetted, and placed on the back of the hand. The paper curls up into a cylinder, the axis of which is parallel to the machine direction of the sheet.

If two strips, each 3 or 4 inches long and about 1 inch wide, cut from the *machine* and *cross* directions respectively, are held together between the thumb and finger at the ends, and allowed to move freely, they behave in a peculiar manner, as shown in Fig. 96.

(1) When the lower strip is that cut in the machine direction, the two pieces hang close together.

Fig. 96.—Determination of the Machine Direction of Papers.

(2) When the lower strip is that cut in the cross direction, it falls away from the upper strip.

The explanation of this test is obvious enough.

Breaking Length.—The strength of a paper may also be recorded by calculating the "breaking length," or the length of paper which, if suspended, would break of its own weight. The data necessary for this calculation are (1) the exact weight of the strip tested, (2) its length, (3) the breaking-strain as found by trial. In the absence of a delicate balance for weighing the strip, the figure may be calculated approximately from the weight of the ream. The following example will serve to show the method of arriving at the breaking length from these data:

Example.—A paper of substance 20″ by 30″, 72 lbs. (480 sheets), is tested for breaking strain on a strip 1 inch wide and 5 inches long, and breaks at 60 lbs.

Since the ream weighs 72 lbs., the weight of a strip 5″ by 1″ can be found.

$$480 \times 20 \times 30 \text{ square inches weigh } 72 \text{ lbs.}$$

$$\text{Hence } 5 \text{ square inches weigh } \tfrac{1}{800} \text{ lb.}$$

If for the 60 lbs. weight necessary to break the paper a length of paper weighing 60 lbs. be substituted, fracture of the suspended length would take place.

As $\frac{1}{800}$ lb. is the weight of a strip 5 inches long, 60 lbs. is that of a strip 240,000 inches long, which is the breaking length, viz., 6666·6 yards.

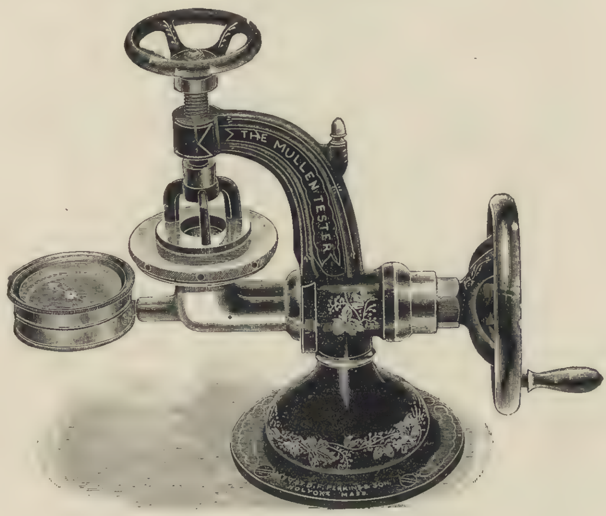


Fig. 97.—Mullen's Paper-tester.

The rule for finding the breaking length is therefore: multiply the breaking-strain recorded on the testing-machine by the length of the strip tested, that is by the length of the piece between the clamps on the apparatus, and divide the product by the weight of the strip.

Bursting-strain.—Machines which register the strength of paper in terms of the pressure necessary to break a sheet fastened between two horizontal clamps are useful because no special precautions are required in adjusting the paper, whereas in the tension machines great care must be exercised not only in cutting the strip to an exact width with edges clear and free of notches, but also in the adjustment of the paper so as to secure correct alignment in the machine between the clamps.

Mullen's machine.—This is one of the most useful appliances of this type. It consists of a small hydraulic cylinder with a pressure-gauge attached. The paper is clamped over one end of a cylinder filled with glycerine, having a flexible rubber diaphragm between the liquid and the paper. The liquid is supposed to conform perfectly to any irregularity in the paper, and thus the pressure acts uniformly. (Fig. 97.)

Southworth's machine.—This works on the same principle as Mullen's, but the pressure is transmitted through a metal piston, which is forced upwards through the sheet of paper. (Fig. 98.)

Woolley's machine.—This is a diaphragm apparatus in which the piston is forced downwards through the paper. The strength of the paper is registered on a scale of arbitrary degrees, whereas in the other machines the pressure is recorded in pounds per square inch. (Fig. 98A.)

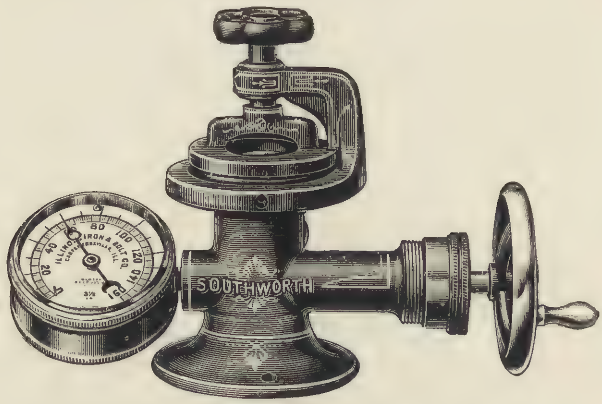


Fig. 98.—Southworth Paper-tester.

Elasticity and Stretch.—These terms are usually applied to the behaviour of paper as it elongates when under the influence of tension on a paper-testing machine. The term stretch is also frequently applied by printers to the behaviour of paper when it expands on becoming moist. The use of the word in this double sense is rather misleading, and it would be better to confine the word "stretch" as meaning the elongation of paper when submitted to tension, and to describe the behaviour of paper when moistened, by the term "expansion."

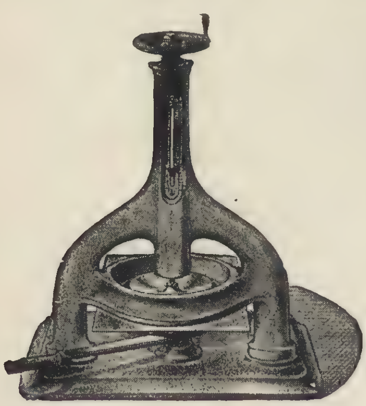


Fig. 98A.—Woolley's Paper-tester.

The stretch of a paper is automatically registered by most paper-testing machines when the paper is examined for strength. Since it varies with the length of paper tested the amount of elasticity or stretch is recorded in terms of the percentage elongation which results from the tension applied. Thus if the elongation on a four-inch strip at the moment of fracture is three thirty-seconds of an inch, then the percentage elongation is 2·3.

There are many interesting points to be observed in connection with the behaviour of a paper when it is stretched.

(1) The paper always stretches least in the stronger direction, and the greatest percentage stretch is found in the weaker direction. In a machine-made paper the maximum stretch is found in the cross direction, and the minimum stretch in the machine direction. This is also true to a limited extent of hand-made papers. It is usually assumed that the strength of a hand-made paper is the same in both directions of the sheet, but as a matter of fact there is always a uniform difference, though not so marked as in the case of machine-made papers.

(2) The elasticity of paper is partly *permanent* and partly *temporary*, the paper behaving to some extent like a piece of metal, since the total elongation produced does not remain permanent when the paper is released from tension. The total elongation, therefore, can be divided into *temporary* and *permanent* stretch, and these qualities can be easily measured in the following manner:

Two pencil lines are drawn on the strip of paper which is to be tested, at any convenient distance apart, the line being drawn at right angles to the length of the strip. After the paper has been fractured, the two pieces are removed from the machine and joined together again at the point of fracture, being laid flat upon a table for this purpose. The distance between the two pencil marks is accurately measured. The increase of distance between the two marks is a measure of the permanent stretch, while the total elongation indicated by the machine shows the total stretch. The difference between the total stretch and the permanent stretch is a measure of the temporary stretch. Some interesting details in connection with this matter will be found in chap. xiv.

Resistance to Wear and Tear.—The methods for measuring the resistance of a paper to friction and folding are for the most part of a purely empirical nature, though in Germany machines are used in the Imperial testing institutes.

The crumpling test.—The paper cut to some convenient dimension of about four or five inches square is crumpled up between the fingers, opened out and then turned over, crumpled a second time, and this operation repeated as often as desired. After each five or six operations, the number of holes appearing in the paper are counted, in order to see the rate at which the paper wears out. For very strong paper at least 120 operations are necessary to produce even a minute hole, but the average run of ledger papers, for example, will show holes much sooner.

Example.—A bank note paper gave the following results:

TABLE XIV.

Number of operations.	Number of holes observed.	
	Sample 1.	Sample 2.
0	0	0
20	2	0
40	3	1
50	7	4
60	12	17
70	20	29
80	29	32
110	56	54

A record of this character is more satisfactory than a general statement that the paper is weak or strong.

The holes produced in the above case were exceedingly small and could only be observed when the paper was held up in front of a strong light. Although this method appears to be rather rough and ready, yet it is a valuable indication of the wearing qualities of the paper. This test, in conjunction with the test which measures the loss of strength due to folding, enables the observer to form quickly and readily a reliable judgment on the merits of two or more papers.

By plotting out the results of the above test in the form of a curve, it may be noted that the number of holes produced is almost in direct proportion to the number of operations, that is to say, up to the limit tried, the increase up to 110 operations being fairly uniform. By continuing the crumpling test it would be easy to find out whether the paper might be expected to wear out gradually or

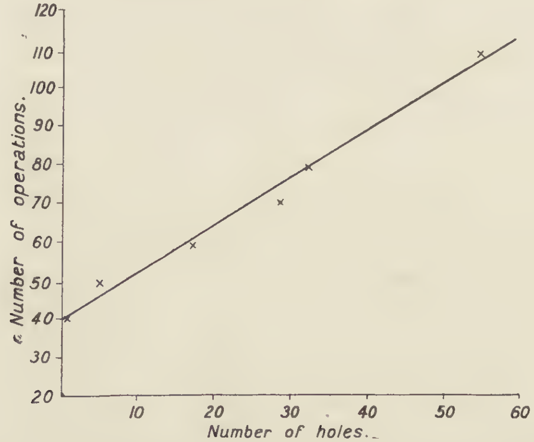


Fig. 99.—Curve to show the effect of testing Paper by crumpling.

to give way suddenly when the friction had reached a certain point. In the case of two papers which give similar results up to about 120 operations, it would be necessary to do this in order to determine finally and definitely the differences between the two.

In the Government testing institutes in Germany the papers are classified for resistance to crumpling according to the descriptions given in Table XV.

TABLE XV.

0. Extremely small.
1. Very small.
2. Small.
3. Medium.
4. Fairly large.
5. Large.
6. Very large.
7. Extraordinarily large.

The only machine for measuring the resistance to folding and crumpling is Schopper's machine, the general appearance of which can be seen from Fig. 100.

Resistance to Folding.—The simplest method of measuring the effect of folding is to ascertain the loss of strength due to repeated folding of strips of the paper. Strips of paper of the same width and length as those taken for the determination of strength, are folded over and over in the middle a certain number of times according to the quality of the paper, and then tested for strength. The loss of strength measures the effect of the folding.

It is advisable to take several strips in each direction, and to note the mean results.

Example.—A paper having a mean strength of 30 lbs. before folding, shows after 150 foldings a strength of 18 lbs. The loss is 12 lbs., giving a percentage loss of 40 per cent.

A simple apparatus has been devised by Kirchner for producing the fold

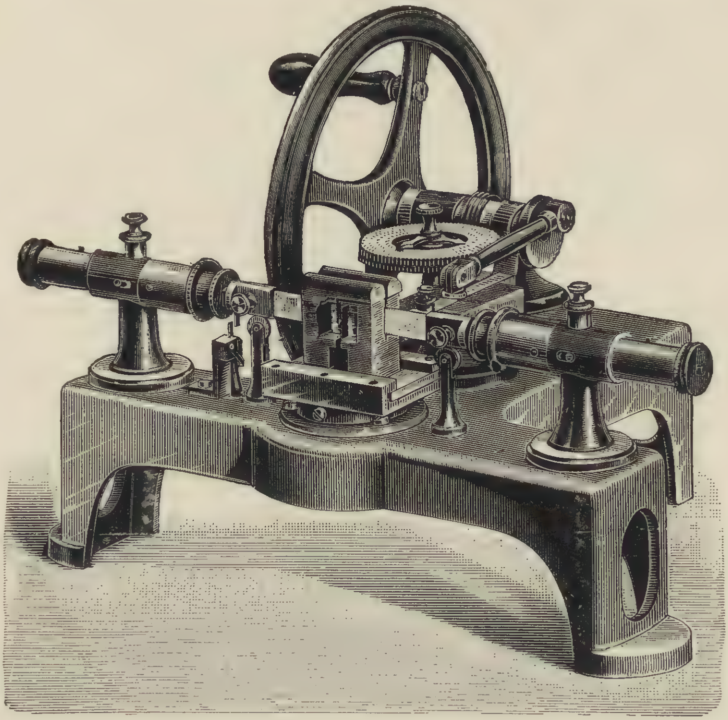


Fig. 100.—Apparatus for testing the Resistance of Paper to Crumpling.

under definite conditions. It consists of a heavy roller working in a grooved block of wood which ensures that the amount of pressure acting on the strip is always the same.

One modification of the test is useful for some papers, especially those which have to be repeatedly folded in actual practice.

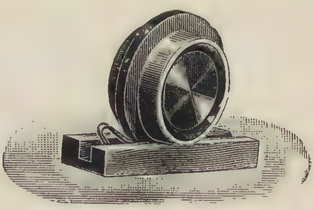


Fig. 101.—Kirchner's Apparatus for testing Resistance to Folding.

For this special folding test, a square piece of paper, six inches by six inches, is cut, the weaker and stronger directions being suitably indicated on the sheet. This paper is then folded in four, the finger of one hand being rubbed with even pressure along the folds away from the centre, one finger of the other hand being kept at the centre in order to prevent the paper tearing away at that point.

The paper having been folded once, is opened up, smoothed out, then turned over and folded again along the same creases. This operation is repeated a certain number of times, the appearance of the centre of the sheet being carefully recorded after each ten foldings.

Table XVI. shows the record for one paper tested in the manner described. Naturally, the remarks are only of comparative value, as they cannot be expressed in numerical terms. The appearance of a small hole at an earlier or later stage of the test is a fairly good indication of what may finally be expected.

TABLE XVI.

Number of folds.	Appearance of centre of Sheet.
10	—
20	—
30	—
40	Minute hole.
50	Slightly larger.
60	Slight crack near hole in one direction.
70	No change.
80	Slight crack near hole in another direction.
90	No change.
100	„
110	„
120	Hole cracked in both directions, $\frac{1}{16}$th inch each way.

After 120 folds, more or less, the paper was opened out, and two strips each five inches long, cut each way of the sheet, as shown in Fig. 102 *c*. The strips were

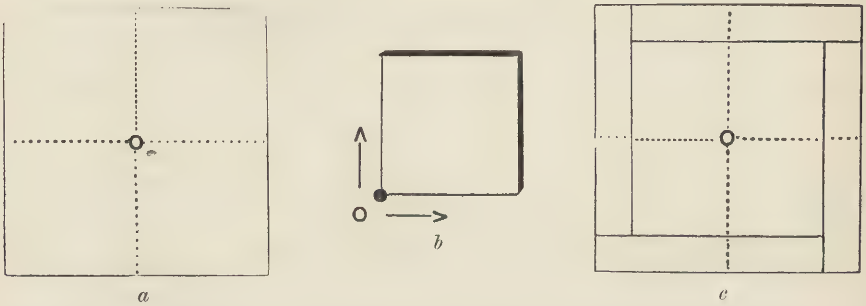


Fig. 102.—Diagram to illustrate Test for Loss of Strength due to Folding. (*a*) Paper six inches by six. Dotted lines indicate position of folds. (*b*) Paper folded in four. Arrows indicate direction of rubbing. (*c*) Paper after folding. Diagram showing method of cutting test slips.

then put into the machine, and tested for strength. The paper naturally broke across the fold or crease, giving the results set out below:

The original strength of the paper in its normal condition was:

Direction A	37·2 lbs.
Direction B	24·0 lbs.
Mean . . .	30·6 lbs

After the test made as described:

Direction A	22·6 lbs.
Direction B	15·0 lbs.
Mean	18·8 lbs.

Thus, the paper having an original breaking weight of 30·6 lbs. still retained sufficient strength after being folded 120 times to require 18·8 lbs. to cause fracture.

Loss due to test = 30·6 less 18·8 = 11·8 lbs., which amounts to 38·5 per cent.

Nature of Tear.—Just as paper behaves differently when it is tested for strength in the two directions of the sheet, so it gives varying results when the "tear" is examined in two directions.

The common method for making a rough comparison between two sheets of paper is to make a slight tear in the sheet of paper in both directions, a judgment being formed as to the general condition of the paper from the appearance of the torn edges and the amount of force required to tear the sheet. Such a comparison is apt to be misleading, as it does not always follow that a paper which tears better than another is necessarily stronger. In the case of hand-made papers, for example, the tear is by no means uniform all over the sheet. A paper may show a strong tear at the deckle edge and a weaker tear if the deckle edge is first removed. Considerable practice is required in coming to a decision that one paper tears better on the average than another, for a very little consideration will serve to show that it is difficult to establish precisely the relation of the "tear" of a paper to its "absolute" strength. The whole of the subject requires a good deal of investigation, and the results would certainly be interesting and instructive.

Generally speaking a paper will tear most easily in the direction which shows the greatest breaking-strain. A greater proportion of the fibres which compose the sheet point in that direction and consequently the tear takes place in between the fibres, so to speak. On the other hand, when the paper is torn across the direction of greatest strength the torn edge will show a far larger number of fibres protruding from the sheet, the tear being *across* the greater number of fibres rather than *parallel* with them.

Sizing Qualities.—The extent to which a paper is sized is determined in a rough and ready manner by the application of the tongue to its surface. If the moisture sinks in rapidly the paper is regarded as being only slightly sized.

Of course an empirical standard of suitability is thus set up, which probably in many cases is sufficient for the purpose, but such a method is quite inadequate when the degrees of sizing have to be compared more closely.

The methods generally employed for testing the water resistant properties, or sizing qualities of paper, may be described under three heads. Attempts have thus been made to express the extent to which a paper has been sized in numerical terms, and although such terms are arbitrary, they afford some degree of comparison.

The test for the strength of sizing may be made: (1) by the writing of characters or lines on the paper with different strong inks.

Three kinds of ink are usually applied to the surface of the paper. The strongest and most penetrating is the ink prepared from logwood, a medium ink being the ordinary fluid obtained from iron and gallnuts, while for weak inks alizarine and aniline colours are used.

The inks can be applied to the surface of the paper by means of a soft quill pen, or better still, with a drawing-pen, the points of which are well rounded, so that the surface of the paper is not scratched in any way on the application

of the pen. A glass tube drawn out to a fine point, well rounded in a gas flame, also acts as an efficient pen. The principal precaution necessary is to take care that the pen does not disturb the surface of the paper.

Evidence of the strength of sizing is obtained by watching the spread of the ink. With a badly sized sheet the ink tends to spread. Then the disappearance of the little ridge of ink produced by the pen, as the ink penetrates the paper, is a useful indication. With a badly sized sheet, the ridge quickly disappears. The following test can be used:

Allow one drop of ink to fall upon each of the sheets of paper to be compared; at first the drop is spherical, but after a while it becomes slightly flattened and covers a larger area. With well-sized papers the drop will retain its spherical form for a considerable period.

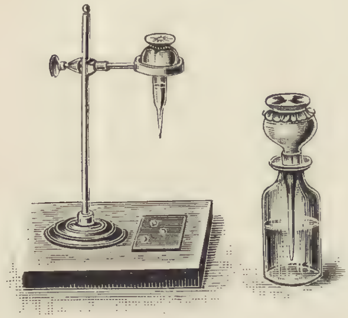
In the ordinary application of the test with these inks, it is usual to draw a cross, consisting of four strokes, two parallel with one another in the horizontal direction, and two parallel with one another in the vertical direction across the former.

(2) Leonhardi's process for estimating the sizing quality of paper is an advance upon the ink method.

A chloride of iron solution of definite strength containing 1·53 per cent. of iron, and a 1 per cent. solution of freshly prepared tannic acid, are required. (Fig. 103.)

Fit up a burette or pipette in a suitable stand, so that the lower end is about four inches from the table. Place the paper to be tested under the burette, and allow one drop of the chloride of iron solution to fall on the surface of the paper. Keep the drop on the paper for as many seconds as may be equal to the weight of the paper in grammes per square metre. Then remove any excess of solution quickly with blotting paper. Reverse the paper, and moisten with the 1 per cent. tannic acid by means of a pad of cotton wool, taking up any excess with blotting paper.

The extent of the coloration is a measure of the strength of the sizing.



a *b*

Fig. 103.—Leonhardi's Test for Sizing Qualities of Paper, with Paper shown in Position.

(*a*) Pipette containing chloride of iron solution.
(*b*) Stock of chloride of iron reagent.

Even this test is merely an empirical one, and the results obtained are of a somewhat negative character. That is to say, one can readily sort up a number of papers into two or three classes, but in the case of samples which may all happen to be well sized no effects will be produced, and in this way the test is of no service in discriminating between well-sized papers. For many purposes such a degree of refinement may be unnecessary, but it is obvious that, under special circumstances, a delicate "surface" test would be useful.

(3) Schluttig and Neumann's method for the determination of the strength of sizing in papers is an ingenious attempt to record this somewhat uncertain property by a numerical expression.

The paper is arranged upon a sloping stand, the sides of which are placed at an angle of sixty degrees. The chloride of iron is not brought upon the paper by means of a drawing-pen, but is allowed to flow from a measuring tube down a grooved plate which is placed above the paper. The solution contains 100 parts by weight of chloride of iron, one part of gum arabic and two parts of phenol. A definite quantity of the solution is employed and three lines are thus produced on

the paper, parallel with one another. The paper is left for fifteen minutes and then reversed, in such a manner that the iron chloride strokes are horizontal. On the reverse side of the paper a solution of tannic acid containing 0·2 per cent. phenol is allowed to flow in precisely the same way. (Fig. 104.)

By this means three horizontal lines of iron chloride solution on one side of the paper are crossed by three vertical lines of tannic acid on the other, forming nine points of intersection. With papers lightly sized, the nine points of intersection appear very black, owing to the contact of the tannic acid with chloride of iron. An intense black colour appears in the paper. With better-sized papers the coloration is less marked, the chemical action taking place inside the sheet below the surface.

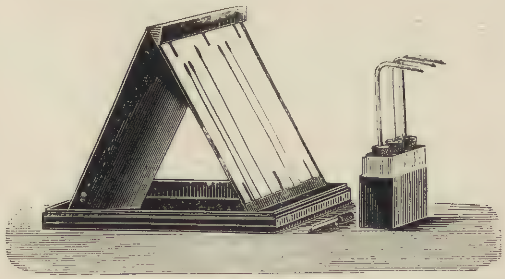


Fig. 104.—Schluttig and Neumann's Apparatus for testing Sizing Qualities of Paper.

The cross points do not colour up equally, and the gradual development of the black colour can easily be watched. With very heavily sized papers no effect is produced at all.

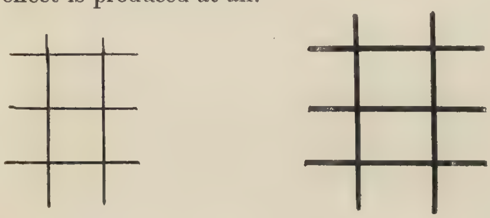


Fig. 105.—Sizing Tests.

The authors of the process claim that they are able to detect small differences in sizing quality, and that the results of their method are in strict accordance with the effects produced by writing inks. They also claim that the penetration effect of a drop of chloride of iron allowed to fall upon the surface of the paper, as in the method of Leonhardi, is not the same as that produced by allowing the solution to flow on at an angle of sixty degrees, as in their process. In the case of highly glazed papers penetration of the ink takes place more readily with the vertical fall of a drop of solution than with the oblique direction.

A modification of Schluttig's method can be tried by drawing three lines of different widths on one side of the paper by means of an ivory-pointed drawing-pen, using the chloride of iron solution, allowing the solution to remain on the paper a given time. The excess of solution is then removed by blotting paper which should not be pressed down, but merely brought into contact with the liquid. The paper is reversed and similar lines drawn at right angles, using tannic acid solution. This is also allowed to remain for a definite period, excess removed as before, and the development of black marks at the points of intersection watched for.

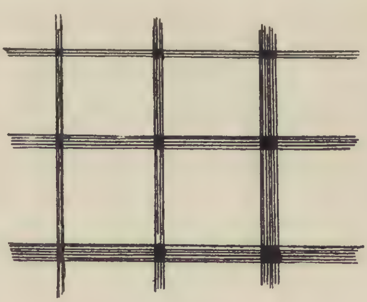


Fig. 106.—Sizing Test.

The method is represented by the conventional diagrams shown in Figs. 105, 106.

Winkler has constructed the following table (XVII.), comparing the various methods, giving a scale of degrees for the "strength of sizing."

TABLE XVII., *showing Classification of Paper for "Strength of Sizing."*

	Schluttig and Neumann's Method.	"Drop Test" (Chloride of Iron).	Ink Test with Crosses.
1. Unsized papers.	The nine cross points blacken almost immediately.	Drops penetrate very quickly. Black colour appears immediately.	Ink penetrates and spreads quickly.
2. Moderately sized papers.	One or two of the latest formed cross points do not blacken.	Drops require at least one minute for penetration and colour reaction.	The thick strokes of the cross soon penetrate, but the thin ones take longer.
3. Well-sized papers.	Four of the latest formed cross points will only become slightly tinted after fifteen minutes.	Drops take at least three minutes to penetrate.	The thick strokes take longer to penetrate; the thin ones do not penetrate.
4. Very well-sized papers.	No coloration after fifteen minutes. A longer time may give a slight grey tint.	Drops take more than five minutes to penetrate.	Thick strokes seldom penetrate.
5. Extremely well-sized papers.	The whole of the cross points remain colourless for any length of time.	No coloration.	No penetration.

Absorptive Capacity.—The capacity of a paper for absorbing moisture may be determined by one or two methods. This quality is of the greatest importance in blotting papers, filter papers and copying-papers.

A rough comparison of blotting papers is generally made by observing the effect of applying the various papers to characters written on a sheet of highly glazed paper. The general behaviour of the blotting paper when some ink is thrown upon it from a pen is also observed.

Strip tests with water.—The capacity for absorption is expressed in numerical values by means of a simple appliance. Strips of blotting paper about half an inch wide and six inches long are suspended in any convenient manner.

These strips are then suspended with the lower end dipping into water, to the depth of about a quarter of an inch. The water rises rapidly at first, and then more slowly as the paper becomes saturated. The height to which the water rises in ten minutes is then noted.

In making this test it is advisable to note the time taken for every half-inch from the surface of the water. Some papers will give a rapid absorption for the first five minutes and then show a great falling off in the rate. Other papers will absorb more evenly all the time. These points should be carefully noted because they afford additional evidence as to the value of the paper.

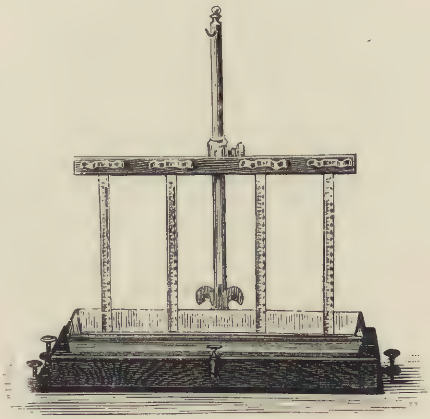


Fig. 107.—Apparatus for testing the Absorbency of Paper by the "Strip" Method.

Dr. Klemm has constructed a scale of degrees for use in his laboratory, as shown in Table XVIII.

TABLE XVIII.

Height of absorption after 10 minutes.	Relative absorbency.
Less than 20 mm.	Very poor.
,, 20 to 40 mm.	Poor
,, 41 ,, 60 ,,	Fair.
,, 61 ,, 90 ,,	Good.
More than 90 ,,	Very good.

Strip tests with ink.—A similar test for absorbency, using Stephen's blue-black ink in place of water, affords valuable information.

This test can be still further extended by allowing the strips of blotting paper to become perfectly dry and then submitting the same strips to the ink test a second time. Poor blotting papers will show a marked reduction in the absorbency when put to this severe test.

Blot tests with ink.—Another test much used by stationers and users of blotting papers is to make a large blot on the paper and allow the blot to dry. If the paper is a good one the blot will appear even and uniform, but if the paper is defective the blot is surrounded by an outer ring of different appearance to the inner zone.

If this test is made under strictly comparative conditions some useful indications of quality can be obtained.

The test may be applied as follows :

The paper in the form of a sheet four inches square is placed under the end of a small burette containing Stephen's blue-black writing ink. The paper is so arranged on a tumbler that the blot will form freely without

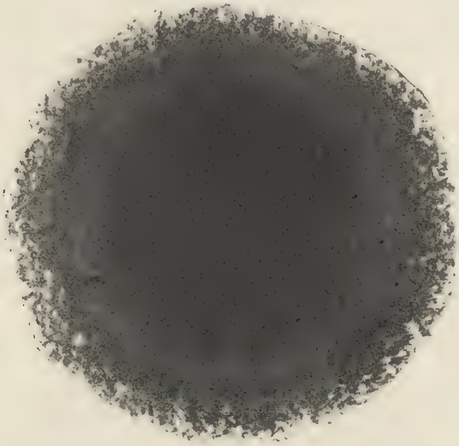


Fig. 108*a*.—Blot of Ink produced on Paper of Good Quality. Outer zone small.

touching the edges of the tumbler, with its surface about half an inch below the burette. A definite quantity of ink, half a cubic centimetre, is dropped on to

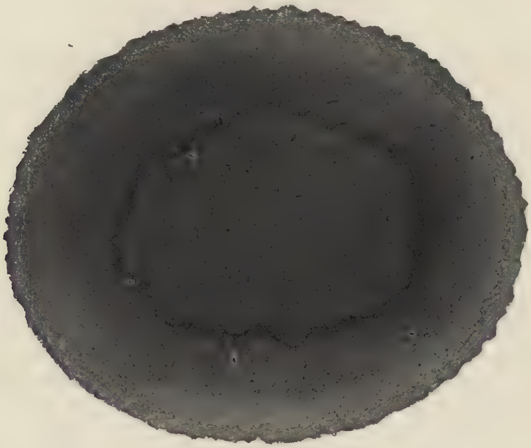


Fig. 108*b*.—Blot of Ink produced in Paper of Bad Quality. Outer zone large.

the paper, drop by drop, each drop being absorbed before the next is allowed to fall. The time occupied in absorbing this quantity is also noted. When the blot dries out the diameter of the rings is calculated.

Now the points to be noted in connection with the blots are:
(1) The time required to produce a blot under the conditions set out.
(2) The total area or size of the blot.
(3) The proportion of the area occupied by the outer zone.
Some experimental results are embodied in the following tables:

TABLE XIX., *showing Time required to produce a Blot from* 0·5 *cc. Ink.*

Sample.	No. of Seconds.
1	1100
2	30
3	210
4	140
5	63
6	180

TABLE XX., *showing Total Area of Blots and Areas of Zones* (*square inches*).

Sample.	Outer zone.	Inner zone.	Total area.	Area of outer zone if total equals 100.
1	3·6	1·4	5·0	72·0
2	0·37	4·15	4·52	8·2
3	0.87	6·2	7·07	12·3
4	0·40	6·1	6·5	6·1
5	0·7	4·1	4·8	14·8
6	2·13	3·12	5·25	40·5

TABLE XXI.—*Absorption Height in* 10 *minutes, in millimetres.*

Sample.	Distilled Water.	Stephen's Blue-black Ink, First Absorption.	Stephen's Blue-black Ink, Second Absorption.
1	1·5	0·5	Nil
2	5·8	5·0	4·1
3	2·2	1·8	1·8
4	2·6	2·3	2·3
5	3·9	3·2	2·2
6	2·4	1·6	0·5

It is well known that the formation of a large outer zone indicates a poor quality of paper. If lines are carefully ruled across the blots in ink the nature of the outer zone is at once revealed, by the non-absorbing character of the surface of the paper which is covered by the outer zone.

Some curious results are obtained by producing a blot of ink *in situ* on the paper by means of tannic acid and ferric chloride. A blot is first formed on the paper by means of a 10 per cent. solution of ferric chloride, half a cubic centimetre being used as before. The yellow stain produced is allowed to dry, and half a cubic centimetre of tannic acid is allowed to drop on to the centre of the

yellow stain, the paper being turned over before the application of the tannic acid. A black ink mark is obtained owing to the combination of the two chemicals. The results obtained are very striking, and should be capable of

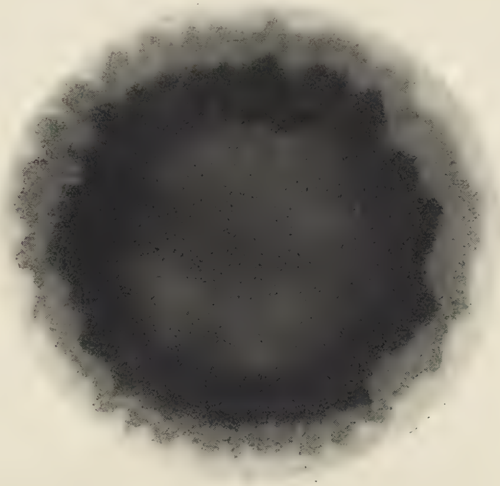


Fig. 109*a*.—Effect of producing a Blot by means of Iron Chloride and Tannic Acid in a Paper of Good Quality.

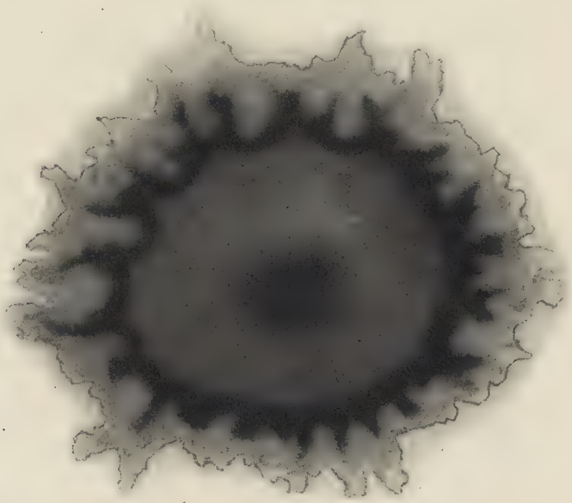


Fig. 109*b*.—Effect of producing a Blot by means of Iron Chloride and Tannic Acid in a Paper of Poor Quality.

interpretation as a means of affording further knowledge as to the capacity of the paper for absorbing moisture.

Filter Papers.—Professor Herzberg has devised a simple apparatus for testing filter papers.

It consists of a long glass tube, the bottom of which is connected to a metal U-shaped tube provided with a tap. The sheet of the paper to be tested is inserted between the open end of the U-shaped piece, and a small cap which can be fastened above the sheet of paper. The working of the apparatus is self-evident from the diagram. Water is maintained in the tube at a constant level, and the water which flows through the paper is caught in a measuring flask. For filter papers a rapid flow is desirable. For waterproof papers the cap can be modified in shape so as to form a simple clamp for holding the paper in position.

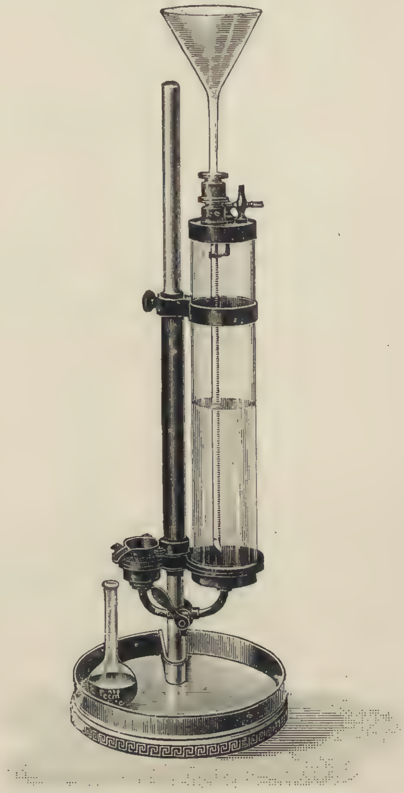


Fig. 110.—Herzberg's Filter Paper Testing Apparatus.

Imperviousness to Water and Air.—The capacity of a paper for resisting moisture, as distinct from the extent to which it is sized is a quality peculiar to special papers, such as waterproof and grease-proof papers.

An approximate method for testing the water resistant properties of a paper is to immerse a sample of the paper in the water for a few moments, and then to weigh the paper after removing very carefully all excess moisture from the surface by means of blotting paper.

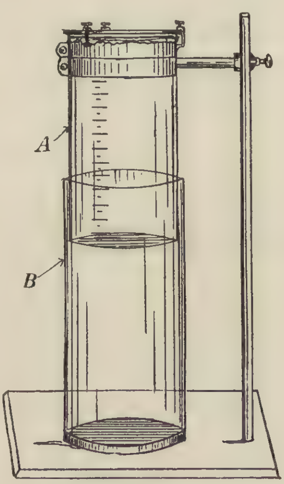


Fig. 111.—Apparatus for Testing Airproof and Waterproof Condition of Paper.

A more accurate method is to fasten a piece of the paper securely to the end of a long glass tube. The tube is then filled with water to any desired height, and the effect of the pressure of the water on the sheet of paper which forms the bottom of the tube carefully noted. A poor paper will allow the moisture to pass through, so that the under surface of the paper becomes moist.

An apparatus suitable for testing how far a paper is impervious to air is shown in Fig. 111. It consists of a hollow glass tube A fitted at the upper end

with a suitable clamping arrangement, by means of which a sheet of the waterproof or grease-proof paper can be firmly fastened down at the upper end of the glass tube. The tube is then lowered into another vessel *B* containing water. The compression of the air inside the tube *A*, caused by immersing the lower end into the water contained in *B*, exerts a pressure on the sheet of paper. At the commencement of the test, the height at which the water stands in the tube *A* is carefully noted. If the paper is not impervious to air, the water will gradually rise to a higher level in the tube *A*, owing to the escape of air through the pores of the paper.

The "blister" test is sometimes used for grease-proof papers. The blister caused by a lighted match brought into contact with the under surface of the paper is due to the formation of steam in the paper from the natural moisture always present in it. The outer surface of the paper being presumably waterproof does not allow the steam to escape rapidly. Turpentine oil can also be used with advantage. Grease-proof paper of good quality will not allow turpentine to pass through, and the additional advantage of the use of turpentine is that small holes which sometimes occur in parchment paper are readily detected, whilst the blister test does not show them.

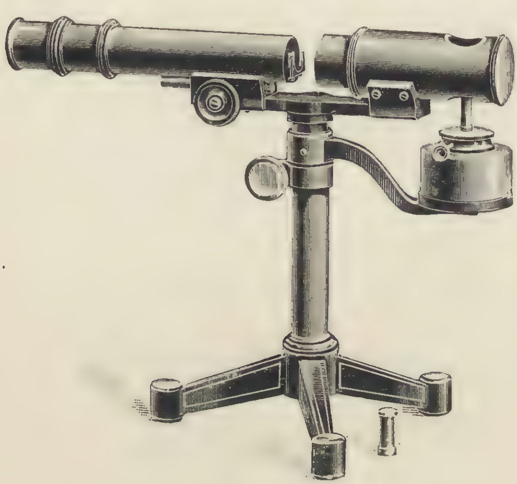


Fig. 112.—Apparatus for the Measurement of the Transparency of Paper.

The Transparency of Paper.—The transparency of a paper may be expressed in terms of the number of thicknesses of paper which must be placed between the eye of the observer and a standard light of known power in order to completely intercept the light.

Dr. Klemm has devised a simple apparatus for the accurate measurement of transparency, which consists of an illuminating tube and an observation tube. Between the two tubes is mounted the arrangement for holding the sheets to be tested, the number of which is increased until they completely intercept the light. This number, multiplied by the weight per square metre, gives the relative transparency. The luminous field is furnished by a Hefner–Alteneck amyl-acetate lamp of one-candle power mounted at a distance of 10 centimetres from the end of the ground glass disc which forms the inner cover plate. The distance of the observation tube (the normal length of which is 25 centimetres) is regulated to suit the observer's vision by means of a rack and pinion. The cover plate of the inner end of this tube consists of a square frame provided with hooks to hold the sheets as they are placed in the frame. As each fresh sheet is inserted, the observation tube is screwed back till it touches the glass plate of the illuminating tube so as to hold the sheets in a vertical position. Stray light is avoided by a cap covering the illuminating tube.

The number of sheets required to render the light invisible is a measure of its transparency. If, for example, twenty sheets of paper are required to obliterate

the light, the paper will be one-twentieth of the thickness necessary to render it opaque. This fraction is a measure of the absolute transparency of the paper.

By taking the weight of the paper into consideration, then the relative value of the transparency of the paper can be expressed in simple numerical terms.

Example.—Let number of sheets used to obliterate the light be N.
Let W equal the weight of a given area of paper.
Then relative value of transparency is WN.

Colour and General Appearance.—These properties of a paper are not usually expressed in numerical terms, as it is exceedingly difficult to find methods of recording them. The only means for registering the colour of paper is by the use of an instrument known as the Tintometer. This instrument is employed in many industries, such as the manufacture of sugar, paint, oils, soaps, iron, steel, flour, &c.

The optical part of the apparatus B consists of a double parallel-sided tube of square section, fitted with plain holes for binocular vision C, and with grooved partitions at the lower end J. The instrument can be tilted to any required angle. (Fig. 113.)

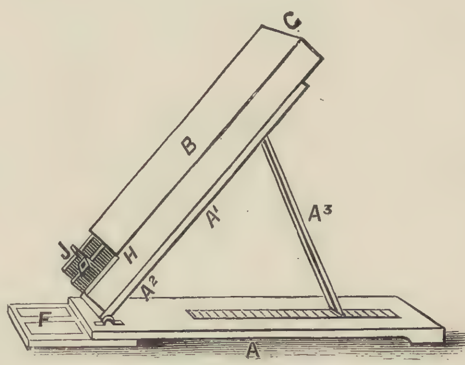


Fig. 113.—Tintometer.

The opaque substance to be measured is placed on the foot of the base F, opposite one of the tubes, and a standard white surface is placed by its side opposite the other tube. Standard coloured glasses are then inserted in the grooves of the tube opposite the standard white surface until the colour of the latter, viewed through the apparatus, matches the unknown or unmeasured colour.

The standard white surface is prepared in the following way: "A represents two pieces of glass, one larger than the other, cemented together, the smaller piece just fitting into B, which is a rectangular frame $\frac{1}{10}$ of an inch deep; this fits to a tray C, also $\frac{1}{10}$ of an inch deep. B and C are fitted together, filled with the standard white substance, and the latter is then levelled off; the powder is pressed lightly down with the small side of the glass presser, in order to remove the frame B more easily from the tray C. The broad side of the presser is used to compress the powder even with the sides of the tray. The whole arrangement is shown in section at D." (Fig. 114.)

The tray is placed at F, opposite one tube, and the paper to be matched previously pinned on to a small block of wood equal in size and height to the tray, opposite the second tube.

The insertion of coloured glasses is an operation which is readily mastered after a little practice and assistance from some one accustomed to the instrument.

The standard glasses.—A complete series of glasses consists of 155 slips for red, yellow, blue; making 465 in all, but a full set is only required when very marked differences in colour are being measured. The gradation in each colour is the same, commencing with ·01 (as the lowest practical unit, although others lower

still can be used), and reaching to 20 units. A combination of three glasses in one colour, each of the value of one unit, will give the same effect as the one glass marked 3 units. A combination of red, yellow and blue in equal units of each will produce a neutral tint light or dark, according to the units employed.

In the analysis of an orange coloured paper three glasses were used, red having a value of 4·4 units, yellow, a value 2·8 units, and blue 1·2 units.

The colour of the paper is not permanently recorded in terms of the standard glasses used, although these are of course registered for reference.

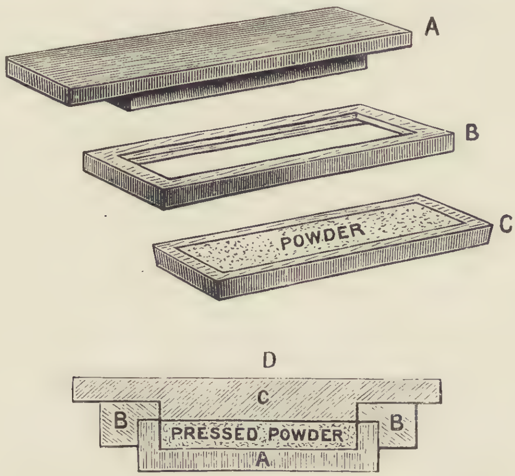


Fig. 111.—Apparatus for obtaining a Standard White Surface.

The visual sensation produced by a colour may differ from that recorded by the standard glasses used. Three equal units of the standard colours absorb light and produce a greater or less degree of black. Hence when all three are used, the smallest value is recorded as black. Thus, as the standard glasses used were :

Red.	Yellow.	Blue.
4·4	2·8	1·2

The visual composition, as it is termed, is :

Black.	Orange.	Red.
1·2	1·6	1·6

a record which, to a colour analyst, is an exact measurement of the colour in figures, and which in words may be termed a dark orange-red.

Table XXII. gives a number of colour readings for some well-known papers.

TABLE XXII.—*Colour Analysis.*

Paper Examined.	Light brighter than Standard.	Standard Glasses used. Red.	Yellow.	Blue.	Visual Colour.		
Sphere		·02	·20			Orange ·02	Yellow ·18
Daily Telegraph . .	·006		·20		Neutral ·006		Yellow ·20
Daily News . . .			·30	·10		Green ·10	Yellow ·20
Westminster Gazette .			·56	·56		Green ·56	
Pearson's Weekly (cover)		6·6	·80			Orange ·80	Red 5·8
Strand Magazine (cover) .			·50	1·6		Green ·50	Blue 1·1
Post Office Telegram Envelopes		4·0	2·6	·50	Black ·50	Orange 2·1	Red 1·4
Post Office Telegram Forms		·50	·40			Orange ·40	Red ·10

Surface and Finish.—These qualities of a paper cannot be recorded by any numerical expression. The amount of finish in a sheet of paper is largely a matter of taste, and the paper-maker can modify it to suit the requirements of his customer. Under these circumstances it is only possible to describe the paper in general terms.

Feel and "Handle" of the Sheet.—These are definite qualities by which the merits of a sheet of paper are largely judged. Stationers and printers frequently decide between two papers by the difference of "handle" when the papers are rattled and shaken by hand. As a matter of daily experience it is found that good papers rattle considerably when shaken between the fingers, and this is usually regarded as a sign of good quality.

CHAPTER X

THE CHEMICAL CONSTITUENTS OF PAPER

Normal—China-clay—Sulphate of lime—Barytes—Agalite—Determination of ash—Nature of loading—Moisture—Starch—**Sizing materials**—Gelatine—Casein—Rosin size—**Abnormal**—Acid—Chlorine—Sulphur—Metallic impurities.

The Normal Chemical Constituents.

THE term "normal chemical constituents" may be used as referring to all the ordinary substances found in paper which are not actually vegetable fibres, and as distinct from adventitious matter in the shape of impurities.

Under such a classification would be considered:

1. Mineral substances added as loading.
2. Mineral matter used for improving surface.
3. Materials necessary for sizing the paper.
4. Pigments and colouring-matters.

However free from added mineral substances, all paper contains a proportion of constituents which are not actually cellulose. The most highly purified form of paper is the specially prepared "filter paper" of Messrs. Schleicher and Schüll, from which the natural mineral constituents have been removed by means of hydrochloric and hydrofluoric acids. This paper contains only 0·02 per cent. of ash.

In strong contrast may be noted many of the highly glazed, surface-coated papers used for half-tone printing, containing 33 to 38 per cent. of their weight of mineral matter, and 8 to 10 per cent. of common glue, leaving only about 50 per cent. of actual fibre.

Mineral Substances.—Although many substances have been employed from time to time as loading for papers, the list of those in common use is not large.

China-clay.—This mineral is used in large quantity as a filler for news, cheap printings, and common writings. It is a natural product found principally in Cornwall, England, formed by the gradual disintegration of *felspar*, through exposure to air and moisture. It is a hydrated silicate of alumina, having the approximate composition represented by the formula:

$$Al_2O_3\ SiO_2 + 2\ H_2O$$

and its average percentage composition is approximately:

Silica, SiO_2	43·00	per cent.
Alumina, Al_2O_3	35·00	,,
Chemically combined water, H_2O .	10·00	,,
Natural moisture	10·00	,,
Impurities, etc.	2·00	,,
	100·00	,,

Its specific gravity is 2·5. The better qualities are free from iron, the absence of which is desirable in clays used for the finer papers.

When the percentage of ash in a common paper exceeds 3·00, it may be assumed that the ash is due to china-clay, or kaolin, used as a loading.

The examination of a residue for china-clay depends on certain reactions of clay when treated with suitable test chemicals.

China-clay is insoluble in water, dilute acids, and alkalies. Concentrated hydrochloric acid in the cold decomposes it partially. Prolonged boiling with strong sulphuric acid decomposes it, giving an insoluble silica and a soluble sulphate of alumina.

Under the microscope the particles of clay appear irregular in shape and size.

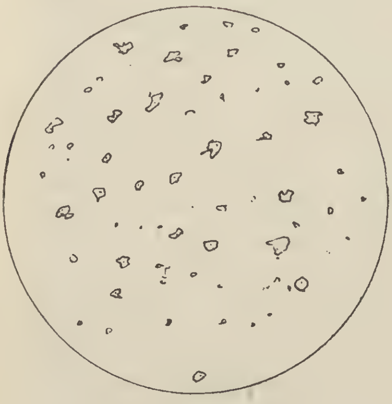


Fig. 115.—China-clay.

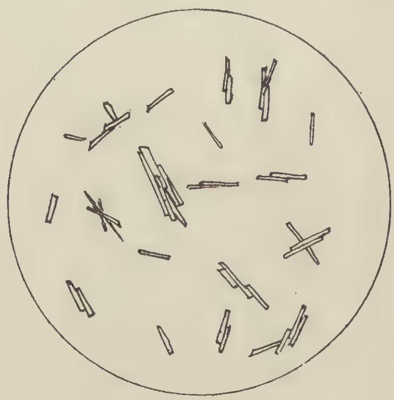


Fig. 116.—Asbestine.

Silicates of Magnesia, under the more familiar names of agalite, talc, French chalk, asbestine, are occasionally found in paper, and may be recognised under the microscope by reason of their crystalline structure.

The exact analysis of the mineral matter or ash which is left behind in a crucible as the result of burning a known quantity of paper demands considerable chemical knowledge and skill. If it is known that the ash, for example, is either *china-clay* or *pearl hardening*, a simple test with hydrochloric acid, as already described, would be sufficient, but the examination of complex mixtures can only be made by a competent chemist.

Sulphate of Lime.—A white crystalline substance, somewhat heavier than china-clay, used chiefly for the better qualities of writings and printings. It occurs under many trade names, such as gypsum, powdered plaster, annaline, which are prepared by grinding the natural mineral; or as pearl hardening, satinite, terra alba, mineral white, prepared artificially by adding sulphuric acid to calcium chloride.

Sulphate of lime is partially soluble in water, and dissolves more readily in dilute hydrochloric acid. If the ash of a paper dissolves when warmed with dilute hydrochloric acid, the presence of this substance may be suspected and subsequently confirmed by chemical analysis.

A microscopic examination of the sulphate of lime will usually determine whether the natural ground product or the precipitated form of mineral has been used.

Barium Sulphate.—A heavy white substance having a specific gravity of 4·4. The natural mineral when powdered is used under the name of Heavy

Spar. The precipitated form prepared by adding sulphuric acid to a soluble barium salt, such as barium chloride, goes under the trade names, Blanc Fixe, Permanent White.

It is used in considerable quantities as a suitable mineral for coated papers on account of its purity of colour and brilliancy. When mixed with precipitated aluminium hydrate it is used as a paste for art papers under the name Satin White.

Barium sulphate is insoluble in water and acids. It can only be rendered soluble by fusion with a mixture of carbonates of sodium and potassium in a platinum crucible. The fused mass is boiled with water, filtered, and the residue dissolved in hydrochloric acid. The examination of a mineral residue in the ash of paper for barium sulphate is based upon this procedure.

Examination of the Ash of Paper.—A proper knowledge of chemistry is indispensable for an adequate analysis of the ash of paper. It is impossible to deal with the subject fully in an elementary treatise, and the following tests only indicate approximately the nature of the mineral residue.

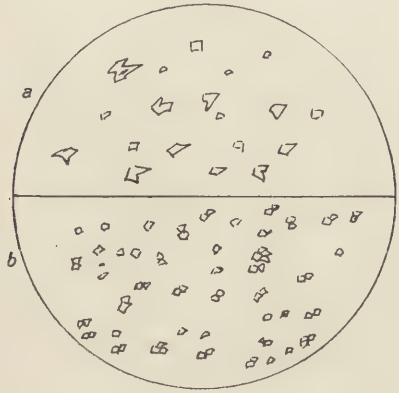


Fig. 117.—Sulphate of Lime.

a. Ground Product.
b. Precipitated Product.

(A) *The ash is quite white.*

If the ash is entirely soluble in dilute hydrochloric acid when heated in a test-tube, china-clay, barium sulphate, silicates of magnesia are absent. If no effervescence takes place when the acid is added, carbonate of lime is absent.

The ash is probably *Sulphate of lime.*

The presence of this compound may be confirmed by dividing the solution into two parts, adding some barium chloride solution to one, when a heavy white precipitate will be produced; and adding sufficient ammonia to the second to completely neutralise the acid, followed by a solution of ammonium oxalate, when a white precipitate will form.

If the ash is treated with dilute acid as described, any sulphate of lime present is dissolved out, and may be detected by the special test given. If the precipitates mentioned are only produced as mere traces, then the ash merely contains traces of sulphate of lime derived most probably from the hard water used in the manufacture of the paper.

Any residue insoluble in hydrochloric acid may contain china-clay, barium sulphate, or silicates of magnesia.

It is dried in a platinum crucible and then fused with a mixture of sodium and potassium carbonates. When cold, the mass is treated with hot water, filtered, and the residue dissolved in hydrochloric acid, which solution is then added to the hot water extract.

The silicates in this way yield free silica and soluble salts, and the barium sulphate gives soluble barium chloride.

If the solution is quite clear, *china-clay* and *silicates of magnesia* are absent.

The ash in this case is probably *sulphate of barium.* It is confirmed by adding some dilute sulphuric acid to the solution when a heavy white precipitate is obtained.

If the solution is not clear, but contains a flocculent gelatinous bulky

precipitate, then silicates of alumina (indicating china-clay) and of magnesium (indicating agalite, asbestine, &c.) may be present.

The silica is carefully filtered off, and the clear filtered liquor examined for alumina and magnesia.

A portion of the solution is heated in a beaker, and ammonia cautiously added until the liquid retains a permanent smell of ammonia. If no precipitate is produced, showing the absence of alumina, then the original ash contained no china-clay.

If a copious gelatinous precipitate is obtained alumina is present, and indicates that the ash contained china-clay.

The solution, if no precipitate is produced, is cooled and a weak solution of sodium phosphate added to it. A crystalline precipitate obtained indicates magnesium, and this may be taken as a proof of the presence of one of the silicates of magnesia.

The solution, if a precipitate is produced, is boiled for ten minutes in order that all the alumina may be completely separated out. It is then filtered and examined for magnesium as described. Absence of the characteristic crystalline precipitate when sodium phosphate is added indicates the absence of any silicates of magnesia in the ash of the paper.

(B) *The ash is coloured.*

If the ash derived from the burning of a paper is coloured, some indication of the *pigment* used as the colouring medium may be obtained. Aniline or vegetable colours are destroyed by the combustion of the paper, and these must be examined by another process.

Blue.—If the ash is blue, *ultramarine*, *prussian blue*, or *smalts* may be present. Smalts is seldom used on account of its high price.

The colour of ultramarine is discharged by dilute acids, but is unacted on by alkalies. The colour of prussian blue is discharged by alkalies, but is not altered by weak acids. The colour of smalts is not affected by acids or alkalies.

A mixture of *prussian blue* and *ultramarine* may be tested by boiling with some caustic soda and filtering. The ultramarine remains on the filter paper unchanged in colour, while the prussian blue passes into solution. A few drops of ferric chloride added to the filtrate, which is first made acid with hydrochloric acid, will re-form the prussian blue as a dark blue precipitate.

Yellow.—If the ash is pure yellow, it suggests *chrome yellow* (canary yellow) as the pigment. The pigment is readily soluble in weak caustic soda solution, which becomes yellow in colour.

If the ash is reddish yellow, of varying shades, the pigment may be *orange mineral*, or one of the many light-coloured *ochres.*

Red.—If the ash is red, some pigment which owes its colour to oxides of iron is present. Such pigments are *venetian red*, which dissolves when boiled in strong hydrochloric acid; *indian red, burnt sienna, red ochre*, which are more or less soluble in a mixture of hydrochloric and nitric acids.

Green.—A greenish coloured ash may be due to the use of a mixture of *blue ultramarine* with *canary yellow.* The ash, if treated with weak acid, loses all its colour; if treated with caustic soda, the yellow pigment is dissolved and the blue ultramarine remains unaltered and can be separated by filtration.

Buff.—This colour is usually due to the addition of nitrate of iron or to some pale coloured ochre.

Brown.—A brown ash may indicate *manganese-brown.* On treatment with dilute hydrochloric acid, a rose-coloured solution is obtained.

Estimation of Ash.—The mineral residue which remains when a known weight of paper is burnt is usually called "ash."

It may vary from 0·02 per cent., as in the case of pure filter papers, to 35 per

cent., which occurs in coated papers, the normal conditions being approximately those shown in Table XXIII.

TABLE XXIII.

High-class writings	1·0 to 4·0 per cent.
Ordinary printings	5·0 „ 12·0 „
Cheap printings	8·0 „ 15·0 „
"Art" papers	20·0 „ 35·0 „

The ash found in papers must not be attributed invariably to what is termed "loading," that is, mineral matter directly added to pulp. In many cases there may be 2 to 3 per cent. of ash present arising from causes of an entirely different character.

In the first place, the fibre always contains a small percentage of natural ash, the amount varying according to the particular class of fibre. The mineral residue in ordinary paper-making materials as given by Herzberg is:

TABLE XXIV.

Bleached linen	0·76 per cent.
Bleached cotton	0·76 „
Sulphite wood pulp	0·50 „
Soda wood pulp	1·40 „
Bleached straw	1·22 „
Mechanical wood pulp	0·80 „
Jute	1·32 „
Hemp	1·00 „

In the second place the chemicals used for sizing and colouring paper give mineral residues also, since the alum, ultramarine, and pigments of various kinds produce ash.

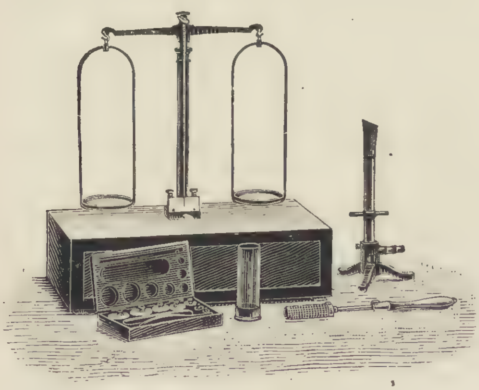


Fig. 118.—Chemical Balance.

The amount of ash in paper is readily ascertained by burning a carefully weighed quantity of paper and weighing the residue.

For this purpose about one gramme of the paper is accurately weighed on a delicate balance, placed in a porcelain crucible and burnt by means of a gas burner or a spirit lamp until all the carbonaceous matter has been driven off. The crucible is allowed to cool and then weighed with its contents, the weight of the crucible when empty having been previously determined.

Example.

Weight of paper taken	1·5300 grammes
Crucible plus ash	16·4300 „
Empty crucible	16·2100 „
Ash	·2200 „

$$\text{Percentage of ash} = \frac{\cdot 2200 \times 100}{1\cdot 53} = 14\cdot 3 \text{ per cent.}$$

If the paper contains only a small proportion of residue, it is better to take two or three grammes, unless the balance is sufficiently sensitive for weighing the traces of ash left from the ignition of one gramme of paper.

Several appliances have been constructed for determining the ash in paper by means of which it is possible to dispense with the ordinary chemical balance and weights, but these are not very largely employed.

The ash balance of Post.—This consists of a delicately suspended lever, to one end of which is fixed a long pointer, and at the other end is fastened a small wire frame or scalepan. The pointer indicates on a scale, divided from 0 to 150,

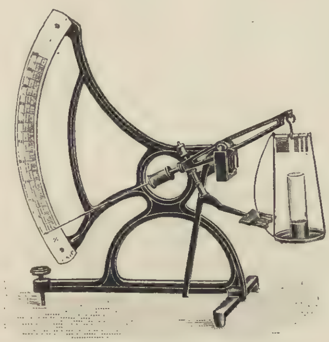


Fig. 119.—Post's Ash Balance.

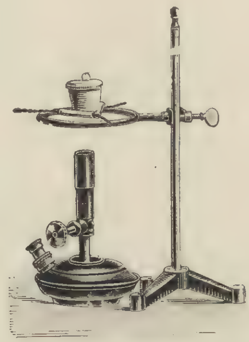


Fig. 120.—Crucible containing Paper, with Bunsen Burner ready for use.

any increase in weight equal to one-hundredth part of a gramme for each division. The balance is used in the following manner: The special platinum wire net provided with the apparatus is placed on the scalepan fixed at one end of the lever, and the instrument adjusted to zero, by means of levelling screws. The paper to be tested is twisted and placed in the wire net, and its weight noted as recorded in divisions on the scale. The wire net with its contents is then submitted to the flame of a Bunsen burner, or a spirit lamp, until the paper has been completely burnt. When the net is cold, it is placed on the balance and the number of divisions on the scale again read off. The reading indicates the relative weight of ash, and from this the percentage of ash can be calculated.

Example.

Number of divisions before combustion . . .	115·5
Number of divisions after combustion . . .	30·2

$$\text{Percentage of ash} = \frac{30{\cdot}2 \times 100}{115{\cdot}5} = 26{\cdot}1$$

It is sometimes convenient to take exactly one gramme of paper, giving 100 divisions on the scale, so that the second reading indicates at once the percentage of ash without calculation.

When frequent determinations of ash in paper are necessary, it is important and often essential to minimise as far as possible all labour involved.

In the paper-mill, for example, the percentage of ash must be determined by the chemist within a few minutes, and every means is devised for this purpose. Usually the rapid and continual testing of papers for ash is a question of proper

manipulation of simple appliances, and not the employment of elaborate and expensive apparatus. A fairly sensitive chemical balance, two or three porcelain crucibles, a spirit lamp or Bunsen burner, an iron tripod, pipe-clay triangles and crucible tongs form a complete outfit. While a specially contrived ash balance and combustion apparatus have certain advantages, the ordinary stock appliances are really more useful, because they can be employed for many other purposes.

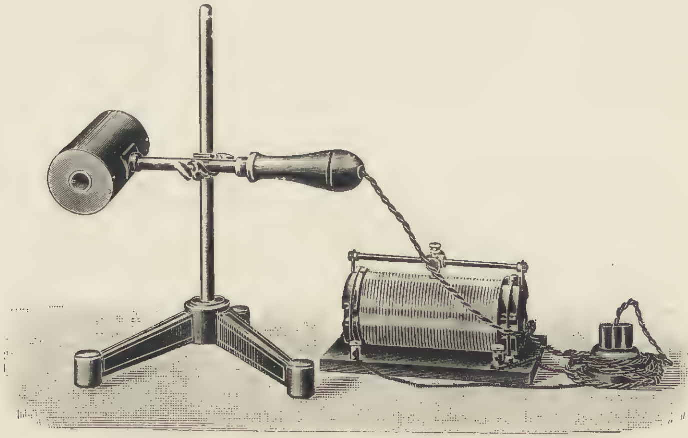


Fig. 121.—Apparatus for burning Paper for Ash Determination by means of an Electric Current.

Moisture in Paper.—As the amount of natural moisture in paper varies according to atmospheric conditions, it is sometimes necessary to determine the exact percentage.

One or two grammes of paper are weighed out exactly and dried at 212° Fahr. in a suitable air bath. The paper, while still hot, is placed in a small weighing bottle which is then placed in a desiccator till cool. The bottle is weighed with its contents, and again weighed when empty, the difference in the two weighings giving the exact weight of the bone-dry paper. From these figures the moisture can be calculated.

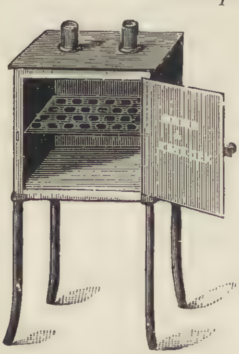


Fig. 122.—Drying Oven.

Example.—Paper taken, 1·50 grammes.

Bottle plus bone-dry paper . .	15·6500	grammes.
Empty bottle	14·3000	,,
Bone-dry paper . .	1·3500	,,

Moisture = 1·50 − 1·35
= 0·15 grammes = 10·0 per cent.

Except under special circumstances a knowledge of the exact variation of the percentage of moisture in paper, due to altered atmospheric conditions, is seldom required. The alterations of the weight of the paper and of the humidity of the air can be observed simultaneously by weighing the paper at intervals during free exposure to the air, and noting the hygrometric condition of the atmosphere by means of a dry and wet bulb hygrometer.

This instrument consists of two thermometers suitably mounted on a stand, one having its bulb exposed to air in the ordinary way, the other having the bulb kept continually moist by means of a cotton wick dipping into a small reservoir of water. When the air is very dry water evaporates quickly from the surface of the wet bulb, which consequently is much cooler than the dry bulb. When the air is damp, evaporation takes place slowly, and the wet bulb thermometer does not indicate a much lower reading than the dry bulb thermometer. (Fig. 123.)

The difference in the readings of the two thermometers is a measure of air moisture, and by reference to special tables the relative humidity of the air, expressed in terms of the percentage of moisture actually present compared with that required to completely saturate it, may be found.

TABLE XXV. DEGREES OF HUMIDITY, SATURATION = 100.

Temp. of the air.	Difference in readings on the two thermometers.											
	1	2	3	4	5	6	7	8	9	10	11	12
32	87	75										
34	88	81	75	70								
36	89	82	75	70	58							
38	90	84	76	71	64							
40	91	84	77	71	65	59						
42	92	85	78	72	66	60	54	49				
44	92	85	78	73	67	61	55	51				
46	92	85	78	73	68	62	57	52				
48	93	86	79	73	68	63	58	53				
50	93	86	79	74	69	63	58	53				
52	93	86	80	74	69	64	59	54	50	46	42	39
54	93	86	80	74	70	64	60	54	50	46	43	40
56	93	87	81	75	70	65	60	55	51	47	44	41
58	93	87	81	75	71	66	60	56	52	48	45	42
60	94	87	82	76	71	66	61	57	53	49	46	43
62	94	88	82	77	72	67	62	58	54	50	47	44
64	94	88	82	77	72	67	62	58	54	50	47	45
66	94	88	83	78	73	68	63	59	55	51	48	46
68	94	88	83	78	73	68	64	60	55	52	49	47
70	94	89	83	78	73	69	64	60	56	53	50	47
72	94	89	84	79	74	69	65	61	57	54	51	48
74	94	89	84	79	74	70	66	61	57	54	51	48
76	94	89	84	79	75	70	66	62	58	55	52	49
78	94	89	84	79	75	71	67	62	59	56	53	50
80	95	90	85	80	76	71	67	62	59	56	53	50
82	95	90	85	80	76	72	63	64	60	57	54	51

The paper can be suspended in any convenient position in a room free from artificial heat, and weighed as required. If a large sheet is hung by some special contrivance to the arm of a Leunig paper-scales permanently for the whole period of investigation, observations can be made conveniently without any trouble.

Starch.—The presence of starch in paper is readily detected by means of a dilute solution of iodine in potassium iodide. A few drops of the iodine test reagent used for microscopic analysis are added to distilled water in quantity sufficient to give a yellow liquid. A blue coloration is almost immediately imparted to papers containing starch, when these are dipped into the liquid. With 4 per cent. of starch, the colour is intensely blue, almost black. Careful observa-

tion of the surface of the paper will usually determine whether the starch was boiled before being used.

The quantitative estimation of starch in paper is a difficult matter. In fact no easy reliable method has been found, and it is usually determined by loss of weight which the paper sustains when extracted with suitable solvents.

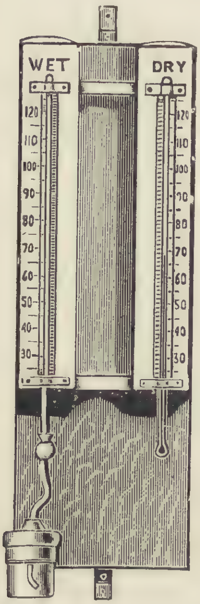


Fig. 123. — Hygrometer, consisting of Dry and Wet Bulb Thermometers.

(*a*) The starch in the paper is converted into glucose with dilute acid, and the glucose sugar estimated by the usual methods with Fehling's solution. Ten grammes of paper, cut into small pieces, is placed in 500 cubic centimetres of water, 2 per cent. of sulphuric acid, calculated on the volume of solution, is added, and the mixture gently heated for three hours at 200° Fahr. until a drop of solution tested for starch fails to give the blue reaction. The glucose is estimated and calculated to starch.

(*b*) The starch is extracted by suitable solvents, and determined by loss of weight.

Two grammes of the paper cut into small strips are boiled for two minutes in absolute alcohol, containing two or three drops of hydrochloric acid. The strips are washed with alcohol, and dried at 100° C.

The loss due to this treatment is that of natural moisture and rosin. The former being readily determined on a separate portion of paper, the *rosin* can also be ascertained by difference.

The strips are next boiled with a mixture of equal parts of water and absolute alcohol, containing a few drops of hydrochloric acid, until the mixture or paper fails to show the presence of starch by the blue colour due to the iodine test liquid.

The paper is then washed with alcohol, dried and weighed. The additional loss is due to the extraction of starch.

Neither of these methods is really satisfactory, both tending to give rather high results.

Fig. 124.—Hair Hygrometer. The moisture is registered by the contraction or expansion of a hair.

Materials used for Sizing Papers.

Gelatine is a transparent, almost colourless, substance possessing little taste or smell. Its composition is :

Carbon	50·2
Hydrogen	6·7
Nitrogen	17·9
Oxygen	25·0
Sulphur, etc.	0·2
	100·0

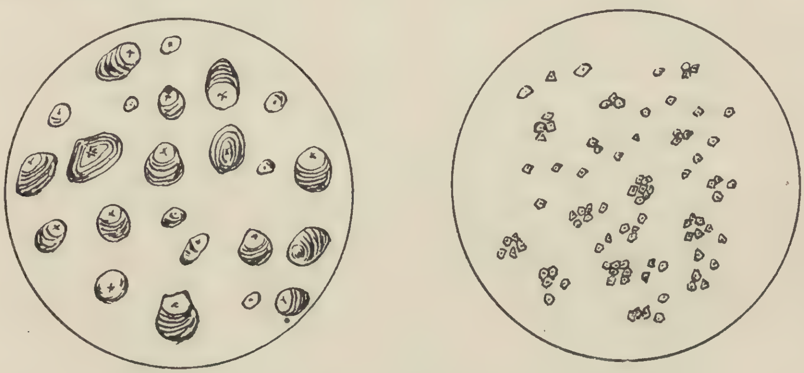
It is insoluble in cold water, but swells up and absorbs nearly ten times its weight of water. It readily dissolves in warm water and sets on cooling to a jelly, even with a strength of 1 to 2 per cent.

Glue.—The terms gelatine and glue are very loosely applied to the substances obtained by boiling down animal tissues, such as skin and hide, the first being regarded as the proper name for the purer forms of gelatine. This is not strictly correct, as there are certain chemical and physical differences in the substances. Pure gelatines are obtained by the action of hot water on carefully selected tissues which will give a colourless, odourless material. Glues are prepared from ordinary tissues which contain bodies with adhesive properties, and the glues obtained vary greatly in colour, smell and adhesiveness.

The term *gelatine* is generally used in the paper trade to denote the more lightly coloured glues.

When paper is coated with a solution of gelatine, or passed through a bath containing the gelatine, it is said to be tub-sized or animal-sized.

The presence of glue or gelatine in a paper may be determined by the reaction with tannic acid.



Potato Starch. Rice Starch.

Fig. 125.—Starch under the Microscope.

A piece of the paper is cut into small strips one inch long and a quarter-inch wide, placed in a test-tube and covered with distilled water. The tube is then heated for ten to fifteen minutes so that the gelatine may be dissolved out. It is better to heat the tube by standing it in a saucepan of boiling water, as prolonged boiling of the actual solution is apt to spoil the test when small percentages only of gelatine are present. The contents of the tube are cooled, and a few drops of a 2 per cent. solution of tannic acid added. A flocculent precipitate forms which, on shaking and gently warming, coagulates and shrinks down into a dark almost opaque horny mass adhering to the sides of the tube.

The reaction is very delicate, but when the amount of gelatine is small the precipitate may not form immediately.

Estimation of the amount of gelatine.—The analysis of a paper for the actual percentage of glue or gelatine is based upon a determination of nitrogen by the Kjeldahl process.

About a half or one gramme of paper (the latter for papers containing a small amount of gelatine), is cut into small pieces and placed in a long-necked "Jena glass" flask *a* (Fig. 126). This flask is suitably supported on a tripod over a Bunsen burner *b*, in a good draught cupboard; 20 c.c. of strong sulphuric acid

free from nitrogen compounds, and two grammes of potassium sulphate are added, and the flask gently heated. When the paper has become charred and partly dissolved, the heat is increased and maintained till the liquid is colourless or merely straw-coloured. It is cooled, diluted with about 400 c.c. distilled water, washed into a large flask *c*, neutralised with a strong 50 per cent. solution of pure caustic soda, enough to turn a litmus paper, previously added to the contents of the flask, blue ; and a few pieces of pumice-stone or zinc added.

The contents of the flask are cautiously distilled through a special condenser *d*, into a flask *e*, containing 20 c.c. (more or less) of decinormal standard sulphuric acid until 150 to 200 c.c. of distillate have been obtained.

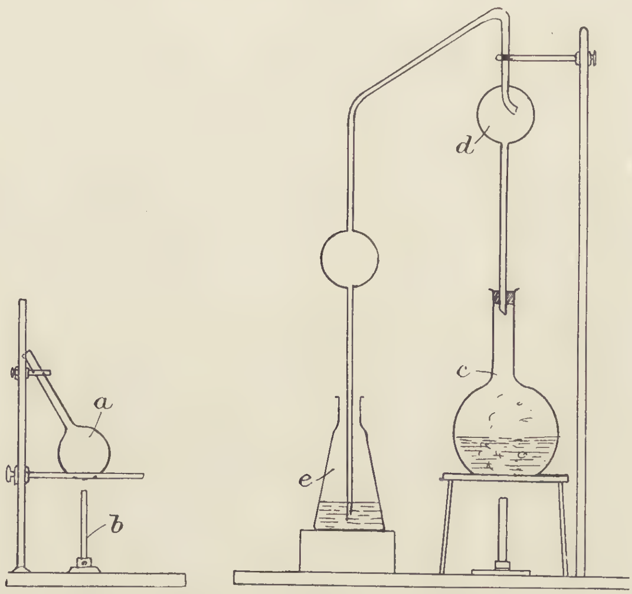


Fig. 126.—Apparatus for determining Gelatine in Paper.

The distillate is cooled and titrated with decinormal alkali solution and the amount of acid still left thus determined. Each cubic centimetre of acid consumed by the liquid distilled over corresponds to ·0014 gramme of nitrogen. The amount of nitrogen multiplied by 5·56 gives the gelatine in bone-dry condition.

The results are more accurate if a small globule of mercury is added to the "Jena glass" flask in which the paper is boiled. In this case a few cubic centimetres of pure strong sodium sulphide solution must also be added to the neutralised liquid in the distilling flask.

Example.—Paper taken, 0·75 gramme.

c.c. of decinormal acid taken . .	20·0 c.c.
c.c. of decinormal alkali used in titration	11·2 c.c.
c.c. of acid neutralised or consumed .	8·8 c.c.

$$
\begin{aligned}
1 \text{ c.c. standard acid} &= \cdot 0014 \text{ gramme nitrogen.} \\
8\cdot 8 \text{ c.c. } \quad ,, \quad ,, &= \cdot 0014 \times 8\cdot 8 = \cdot 01232 \text{ gramme.} \\
&= \cdot 01232 \times 5\cdot 56 \text{ grammes gelatine.} \\
&= \cdot 0685 \text{ gramme gelatine.}
\end{aligned}
$$

$$\text{Bone-dry gelatine in paper} = \frac{\cdot 0685}{\cdot 75} \times 100 = 9\cdot 0 \text{ per cent.}$$

Millon's reagent.—For detecting small quantities of animal size a delicate colour reaction may be obtained by Millon's test.

The reagent is prepared by adding to a known weight of quicksilver an equal weight of fuming nitric acid. The mixture is allowed to stand twelve hours, and then diluted with an equal volume of distilled water. After standing twenty-four hours, the clear supernatant liquor is bottled. The solution remains good for about six to eight weeks.

A drop of the reagent is placed on a strip of the paper, and the paper heated very gently. If gelatine is present, the paper is coloured rose-pink or deep red, according to the quantity.

The reagent gives this coloration with mechanical wood pulp to some extent, and also with casein.

If very old documents, in which traces of parchment are sometimes found, give this reaction, special attention must be directed to a microscopical examination of the paper, since the colour may be due to the parchment, which, of course, contains gelatine.

Casein has been introduced of recent years for sizing, and also as an adhesive for the manufacture of coated papers. It is prepared from skim-milk by treatment with dilute acid, the resultant whey being collected, washed, dried and powdered, and sold as casein in the form of a yellowish granular powder.

In chemical composition it closely resembles gelatine, and the detection of casein as such is not always an easy matter in the hands of a novice. Casein contains a small proportion of sulphur, and this fact is taken advantage of in testing papers for casein.

It is insoluble in water, so that carbonate of soda, ammonia or borax are employed in practice for making working solutions. Thus many coated papers containing casein have a strongly alkaline reaction, the existence of which is determined with litmus paper.

According to Adamkiewicz, casein heated with a mixture of one volume of concentrated sulphuric acid and two volumes of acetic acid is coloured reddish violet, whereas gelatine does not give this colour.

This test can be applied to papers in which casein is present. The paper is boiled with a small quantity of borax, which removes the casein and the insoluble mineral matter. The residues so obtained are boiled down to a small bulk, and treated with the acid mixture. The reddish violet colour appears on warming.

The use of an alkaline solution of lead acetate is recommended by some authorities as a test for casein, but the indications are not always satisfactory. The test is based upon a brownish coloration produced by the contact of the reagent with casein.

Rosin Size.—The substance which produces the sizing effect in paper when rosin soap added to the pulp in the beater is precipitated by alum is not known to possess a definite chemical composition. It is supposed by some chemists to consist of free rosin and by others to be a mixture of free rosin with precipitated resinate of alumina.

The examination of a paper for rosin sizing depends upon the solubility of rosin in alcohol. The paper previously cut up into strips one inch long is placed in a test-tube, with some absolute alcohol and a few drops of acetic acid,

and gently heated on a water bath at a temperature of 75° C. for half an hour. The solution poured into water will give a milky appearance to the water, more or less pronounced according to the amount of rosin.

The following plan may be adopted for extracting comparatively large quantities of paper with a small quantity of alcohol in order to obtain a fairly strong solution :

The paper is cut up into strips one inch by a quarter as before and packed into the bottom of six or eight test-tubes (five inches long being a convenient size for the tubes). The contents of the first tube are treated with alcohol, warmed for 15 minutes on a water bath at a temperature of about 60° to 70° C., and the solution poured off into the second tube. The contents of the first tube are again extracted with fresh alcohol, and the liquid poured off into the second, from which the solution previously added and warmed has first been transferred to the third tube. The extracts are continuously passed through the whole of the tubes, becoming more or less fully charged with soluble resinous compounds. This final extract poured into water gives a decided turbidity.

It should be noted that traces of turbidity will always occur with paper containing mechanical wood pulp on account of the natural rosin in the wood.

It is essential to use only absolute alcohol, or rectified spirits of wine for the purpose of extracting, as methylated spirit will itself produce turbidity when added to water on account of the wood spirit or naphtha oil it contains. A few drops of acetic acid should also be added.

If the concentrated solution obtained by the successive extractions of paper is carefully boiled, in order to evaporate off the alcohol, the resinous matter will be seen as a transparent dark brown mass in the bottom of the test-tube. If heated with acetic anhydride, cooled, and then treated with two drops of strong sulphuric acid, it will develop a violet-red colour.

An interesting test for rosin in paper is the *Raispail reaction.* A strip of the paper is partially immersed in a few drops of concentrated sulphuric acid placed in a watch glass. A violet-red colour develops after a few moments if rosin is present, but no colour is produced when rosin is absent. Tub-sized papers can be examined for rosin size by this test. Mechanical wood in paper renders the test unreliable.

A few drops of ether poured on to a sheet of rosin-sized paper give useful indications. The rosin dissolves and is carried by the movement of the ether towards the edge of the damp ring which forms on the surface. As the ether evaporates, the rosin is concentrated at the circumference and forms a brownish coloured ring.

A delicate test similar to the Raispail reaction can be used for rosin-sized papers. Small strips of the paper are boiled in a test-tube with acetic anhydride for two or three minutes, the liquor poured off into a watch glass and cooled. A few drops of strong sulphuric acid added to the liquor develops a reddish violet colour, which is very fugitive.

This reaction detects small traces of rosin in tub-sized papers and is useful for confirming the presence of rosin in news and cheap printings.

Quantitative estimation of rosin size in paper.—Several methods are available, but it is somewhat doubtful how far the results obtained accurately represent the extent to which the paper was sized when manufactured. The subject requires considerable investigation.

(*a*) Schumann recommends heating a known weight of paper with a 5 per cent. solution of caustic soda at 75° C. for half an hour to dissolve the rosin. The filtrate is then acidified with sulphuric acid, and the resultant precipitate filtered off, dried at 100° C. and weighed. The method is not very reliable, giving high results.

(*b*) A weighed quantity of paper can be extracted with alcohol in a Soxhlet apparatus and the rosin determined by the loss of weight due to extraction.

(*c*) A known weight of paper extracted with alcohol by successive extractions as described above yields a solution containing a weighable quantity of resinous matter. This can be dried and weighed.

(*d*) A simple colour measurement, based on the turbidity produced by pouring the alcoholic extract into water, affords an approximate result. The test is made under the following conditions:

A standard solution of rosin in absolute alcohol is prepared by dissolving 1 gramme of rosin in 100 c.c. of alcohol. The extract from a known weight of paper is added to 50 c.c. distilled water in a colourless glass tube (a flat-bottomed Nessler tube is most suitable). To 50 c.c. of water in another Nessler tube sufficient standard rosin solution is added from a graduated pipette to give a turbidity equal to that produced from the paper. The amount of rosin is thus determined.

Example.—Paper taken, 2·0 grammes.
Volume of standard rosin used 3·0 c.c.

$$\text{per cent. rosin in paper} = 50 \times 3{\cdot}0 \times {\cdot}01 = 1{\cdot}5 \text{ per cent.}$$

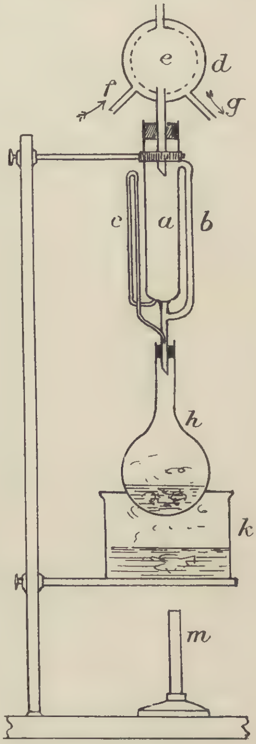


Fig. 127.—Soxhlet Apparatus for extracting Soluble Matters from Paper.

Soluble Matters in Paper.—The Soxhlet apparatus may be used for removing all soluble matters from paper, those soluble in water by means of water, and those soluble in alcohol by means of alcohol.

It is particularly convenient for treating large quantities of paper with small quantities of solvent in order to obtain a solution containing a maximum proportion of extracted matter. As shown in the diagram, the apparatus is fitted up for the extraction of paper with alcohol, to remove bodies soluble in alcohol, such as rosin and aniline dyes.

The paper, previously weighed and rolled up tightly into cylindrical form, is placed in the extractor *a*. The extractor is fitted into the neck of a boiling flask *h*, which rests upon a water bath *k*, heated by means of a Bunsen burner *m*.

In the top of the extractor is fitted a condenser *d*. When the burner is lighted the water boils and heats the contents of the flask *h*. The alcohol boils, passes upwards into the extractor *a* through the side tube *b* and into the internal globe of the condenser. It is then condensed by contact with the sides of the condenser, kept cool by a current of water passing into the tube *f* and from the tube *g*. The condensed alcohol falls back upon the paper in the extractor *a*, and when the vessel *a* is filled the alcohol syphons back automatically through the syphon tube *c* into the flask *h*, carrying with it more or less of the matter in the paper soluble in alcohol.

The process is continuous. After an hour or more, according to circumstances, the paper may be taken out and a fresh piece put in, without disturbing the solution in the flask. In this way a very small quantity of alcohol is sufficient for a large amount of paper. The paper can be dried, and the loss of weight ascertained.

The solution can be kept for subsequent examination.

The Abnormal Chemical Constituents of Paper.

The substances occasionally found in paper which are detrimental to its qualities of colour, durability and appearance may be most conveniently described as "abnormal constituents." They cannot be rigidly classified in the same manner as the normal constituents, nor can they be fully discussed, since they partake of the nature of impurities, some present by reason of careless manufacture, others on account of the use to which the paper has been put. The only adequate discussion of the subject, which is an interesting and important one, must arise from a consideration of specific cases, as suggested in chap. ii.

Free Acid in Paper.—The use of a solution of litmus is scarcely permissible for detecting acidity in papers. In ordinary cases a solution of neutral purple litmus is coloured red by the merest trace of free acid, but with paper litmus may be reddened even in the absence of *free* acid. This peculiarity is due to the presence of sulphate of alumina in small quantity. Alum is a salt which has what is known as an "acid reaction," and turns blue litmus red, so that this colour does not always indicate free acid.

The proper indicator for the detection of free acid is *congo-red*, a reddish colouring-matter which turns blue with traces of free acid.

The suspected paper is cut into strips, and extracted with very small quantities of *distilled water* in test-tubes by the method described for extracting rosin size from papers so as to produce a fairly concentrated extract. The solution is poured out into two or three watch glasses, and test-papers immersed in each, a blue litmus paper in one, a congo-red test-paper in the second.

If the litmus goes red, and the congo-red paper turns blue, the suspected paper contains free acid. If the litmus goes red, but the congo-red remains unchanged, then the acidity is only apparent, being due to the presence of the alum.

The test may also be made by putting one drop each of litmus and congo-red solutions on strips of the paper, allowing them to remain in contact for an hour or more with the strips while covered over with inverted watch glasses.

It is very desirable that papers intended for water-colour paintings, drawings, needle wrappers, steel and ironware wrappers, cover papers upon which gilt letters are to be blocked, and photographic papers, should be quite free from any suspicion of free acid.

Sulphur and Sulphur Compounds.—The presence of sulphur and sulphur compounds in paper is very detrimental. The exceptions may be noted of the normal sulphates, such as barium sulphate, calcium sulphate, and alum, which are innocuous, and occur in most cases as normal constituents of paper.

Sulphur compounds of the undesirable type, which yield sulphuretted hydrogen when heated with dilute acids, are detected by boiling pieces of the paper with dilute hydrochloric acid, the steam being allowed to impinge on acetate of lead test-paper which turns brown when sulphuretted hydrogen comes into contact with it.

These compounds arise from a variety of causes. The use of hyposulphite of soda as an antichlor for killing bleach is apt to produce a precipitate of sulphur.

Badly boiled and incompletely washed chemical wood pulp contains traces of sulphides from substances used in manufacture.

The objections to the presence of such impurities are to be found in the unpleasant smell of the paper, the odour being particularly noticeable when the reams of paper are first opened; also in the serious drawback of a brownish halo round the letters produced with ordinary printer's ink, caused by the action of the sulphur compounds on the oily constituents of the ink.

Free Chlorine and Chlorine Compounds.—Free chlorine, as such, is seldom, if ever, found in finished paper. The paper-maker guards against the presence of any free chlorine in the bleached pulp by testing it with a solution of starch paste to which a little potassium iodide has been added.

Any free chlorine which may remain in the pulp is gradually changed into chlorides, and these may be found in paper as chlorides of sodium, calcium, magnesium, and sometimes iron.

The paper is extracted with distilled water acidified with a few drops of nitric acid known to be free from chlorides. To the extract is added a small quantity of silver nitrate, which will produce a more or less copious precipitate or merely a slight cloudiness, the latter being more frequently observed. The presence of much calcium chloride indicates, as a rule, an incomplete washing of the pulp after bleaching.

Mineral Adulterations.—The addition of mineral matter to paper cannot be regarded as a process of adulteration, unless the presence of loading has been strictly forbidden by contract. The nature of the ash must then be determined by methods already described.

Particles of Metal, Dirt, &c.—The nature of the particles of metal and foreign matter in paper may largely be determined by careful microscopic analysis.

Iron and copper particles may be identified by dipping the paper into weak hydrochloric acid, removing the excess of acid by blotting paper, and then immersing the sheet of paper in a dilute solution of potassium ferrocyanide. Each particle of iron is surrounded by a blue-coloured circle, and the copper by a chocolate-coloured circle.

Particles of suspected coal or coke, when carefully picked out, will, if strongly heated on a piece of platinum foil, burn to a white ash.

CHAPTER XI

THE MICROSCOPE

Description of the instrument and accessories—General hints on the use of the microscope—Mounting, examination and identification of fibres—Exercises for students—Measuring the dimensions of fibres—Reagents for microscopical work

THE microscope is an indispensable instrument for those who have anything to do with the technical examination of papers. By means of it one is able to determine, not only the nature of the fibrous constituents in the paper, but also approximately the proportions in which those constituents are present. The identification of the fibres is a matter which requires considerable experience and constant practice, particularly with papers containing mixtures of fibres which closely resemble one another in physical structure.

The microscope can also be used for the examination of the mineral residues in paper, and for many investigations of an important character quite outside the routine work of ordinary identifications.

The Instrument.—For routine work an elaborate microscope is by no means necessary. The most convenient instrument for general practice is one which permits of a magnification ranging from about 60 diameters up to 300 diameters, the latter magnification being seldom required. The instrument should be provided with a coarse and a fine adjustment, two ordinary eye-pieces, one $\frac{1}{2}$-inch objective and one $\frac{1}{4}$-inch. objective; also a mechanical stage, which is most useful when examining papers for the determination of the proportions of different fibres present.

The writer recommends an instrument made by Messrs. Watson, of Holborn, known as "The Edinburgh Students' Microscope" (Stand H), provided with eye-pieces B and C, together with $\frac{1}{4}$-inch and $\frac{1}{2}$-inch objectives. With this combination the following range of enlargements is possible:

TABLE XXVa.—*Magnifications.*

	Eye-piece. B.		Eye-piece. C.	
Tube Length.	Objective $\frac{1}{2}$ inch.	Objective. $\frac{1}{4}$ inch.	Objective. $\frac{1}{2}$ inch.	Objective. $\frac{1}{4}$ inch.
6 inches.	72	150	96	200
10 inches.	120	252	160	336

From the above table it will be seen that with the eye-piece and objectives mentioned it is possible to obtain a magnification of 72 diameters by using eye-piece B, $\frac{1}{2}$-inch objective, with the tube of the instrument maintained at its

short length; and the magnification of 336 diameters by using eye-piece C, with $\frac{1}{4}$-inch objective, and the tube of the microscope racked out to the full length of 10 inches.

Whatever type of instrument is selected, it is important that the stand should be perfectly rigid, particularly when the microscope is tilted into a horizontal position, the latter condition being necessary when it is desired to make drawings of the appearance of the fibres under the microscope.

General Hints on the Use of the Microscope.

It is a common fault on the part of many students who take up work with the microscope for the first time to imagine that it is best to employ high powers to carry out ordinary investigations. As a matter of fact, it is better to use low powers as far as possible, and to confine the use of higher powers to special investigations on the structure of individual fibres.

Mr. Lewis Wright, a well-known authority on the microscope, further points out that the eye needs educating as well as the hands; that is to say, the expert manipulation of the microscope demands considerable practice not merely as to the use of the various parts of the microscope, but also as to the training of the eye to observe fundamental details, which might at first sight appear of small moment.

As this chapter has been written mainly for the benefit of students who are not familiar with the microscope and its uses, the general hints as to its manipulation have been written in the form of instructions, to be carefully followed out.

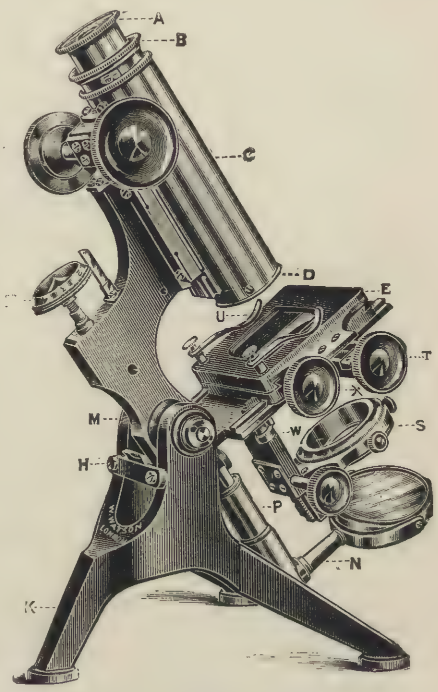


Fig. 128.—A Typical Microscope.

The Instrument.—The base of the instrument called the *foot*, K, is usually tripod in form, which is the best shape for steady work. The body of the instrument can be tilted at any angle between a vertical position and a horizontal position by means of the *pivot* M, the exact horizontal position being insured by a small stop-bar H. The *tube* or *body* G carries at the upper end the *eye-piece* A, and at the lower end the *objective* D. It contains also a sliding *draw-tube* B, so that the length of the body can be varied from about six to ten inches. The body is lengthened merely by drawing out the slide-tube to any required distance. The regulation of the tube is obtained by means of the coarse *adjustment*, consisting of the rack work actuated by means of *milled-head screws* C. The fine *adjustment* F is only required when the higher objectives are used. As the name implies, it is used for bringing the object into exact focus by means of very small movements of the body.

The *stage* E, which is used for carrying the slide, in its simplest form is

merely a square plate with a large hole in the centre, through which the light can be reflected from a mirror N into the microscope.

The *mechanical stage*, as shown in the illustration, is provided with two adjustments, by means of which the body of the stage can be moved horizontally from side to side or from back to front. This movement is most useful in the examination of fibres, though not essential, as it enables the operator to bring systematically into the field of observation all the fibres which may be mounted on the slide. Underneath the slide is the reflecting *mirror* N, which is flat on one side and concave on the other. This mirror is used for reflecting the light from the window through the object on the stage into the tube of the instrument. The mirror is fitted on a *swivel* P, so that when the instrument is in the horizontal position it can be turned aside to permit of the direct light from a lamp being passed through the slide. The *sub-stage* S is used for carrying the various additional appliances, such as the sub-stage condenser, which is necessary in some cases for the examination of objects under high powers. For special work in the examination of fibres the sub-stage is used, for example, when the fibres are being examined under polarised light.

Accessories.—There are a number of additional appliances which should be obtained by those intending to carry out any prolonged study of fibres.

Nose-piece.—This is a simple contrivance that can be attached to the lower end of the body-tube, by means of which various objectives can be quickly exchanged. It is constructed to carry two or three objectives, each of which can be brought into action by a simple rotation of the nose-piece. A double nose-piece is quite sufficient for most purposes.

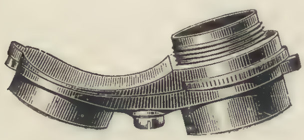


Fig. 129.—A Double Nose-piece for carrying two Objectives.

Millimetre scale.—This consists of a glass slide of the usual dimensions, three inches by one, on which is etched a line divided off by cross lines into equal divisions of one-tenth of a millimetre. One of the spaces is further sub-divided into tenths.

Eye-piece micrometer.—This in its simplest form is a small circle of glass, which fits into any one of the eye-pieces. A number of arbitrary divisions marked 0 to 10 are etched upon the glass.

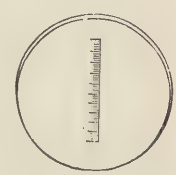


Fig. 130. — An Eye-piece Micrometer Glass, to drop into the Eye-piece.

The micrometer is used in conjunction with the millimetre scale for the measurement of the length and diameter of fibres.

Beale's tint reflector.—This is a useful contrivance, by means of which a drawing can be made of the object examined. It consists of a small piece of transparent neutral-coloured glass supported on a spring, which can be attached to the eye-piece. The microscope is tilted into a horizontal position, and a strong light allowed to pass through the stage so that the image of the object is reflected downwards on to a sheet of paper. This image can be clearly seen on the paper and is readily traced over with a pencil.

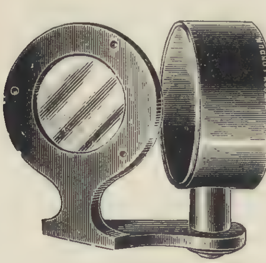


Fig. 131.—Beale's Tint Reflector, simple form.

Lamp.—This is only required for work done when good daylight is not available. For ordinary purposes a common 1*s.* oil lamp will do, though there are plenty of special lamps sold for microscope work.

Slides.—Three or four dozen glass slides of the usual type, measuring three inches long by one inch wide.

Cover-glasses.—These are supplied in boxes and are either square or circular in shape, the most suitable size being five-eighths or three-quarter inch.

Microscope needles.—A few microscope needles, straight or bent, the latter being more convenient.

Drainer.—A small piece of fine brass wire gauze for draining off water from the fibres. An old piece of paper machine wire about three inches square, with the edges doubled over and flattened down answers the purpose admirably. If the piece of wire is placed over the mouth of a small bottle and pressed down with the thumb, a slight circular depression can be made in the wire cloth, which thus forms a convenient receptacle for the disintegrated pulp.

Fig. 132.—Draining Sieve.

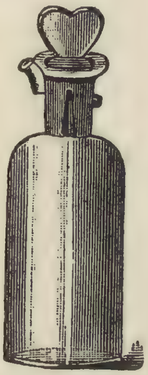


Fig. 133.—Dropping Bottle with Grooved Stopper.

Reagent bottles.—Special bottles with groove stoppers so constructed that the liquid is discharged from the bottle in single drops.

Cabinet.—A small box capable of holding twenty or thirty slides, which can be kept for reference.

Porcelain basins.—Two or three flat-bottomed shallow dishes about three to four inches diameter will be sufficient.

Spirit lamp.—This will be useful for boiling papers and fibres in caustic soda solution.

Elementary Manipulation. — Place the instrument near a window where diffused light is available, avoiding the direct glare of the sun. Adjust the mirror so that the light is reflected through the tube of the instrument, noting that the amount of illumination can be varied according to the angle at which the mirror is tilted.

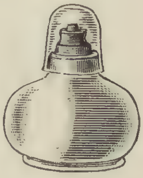


Fig. 134.—Spirit Lamp.

Place a ready prepared slide, preferably one containing some permanently mounted fibres, which can be purchased at any optician's or microscope dealer's, on the stage. Fit the half-inch objective into the lower end of the body-tube, and one of the eye-pieces into the upper end of the tube. Proceed to focus the objective by means of the coarse adjustment, an operation which will require some care. Turn the milled heads of the coarse adjustment so as to bring the objective upwards away from the object until the distance of the objective from the slide is about one inch. Then placing the eye to the instrument slowly rack down the tube until the blurred image comes into view, and continue the movements very cautiously until the image is clearly focused. When the slide contains only a few fibres distributed all over the *field of view*, as it is called, there is sometimes a danger that if none of the fibres happen to be in the direct line of vision the observer may rack down the tube hard on to the microscope slide and injure the objective, or the object.

This danger must be guarded against by careful manipulation. The following course might be adopted by a beginner. Place the slide in position and rack down the tube until the objective is close to the slide, watching the distance between them very carefully to avoid actual contact. Then, placing the eye to the instrument, turn the milled heads of the coarse adjustment so that the focusing is produced by the upward motion of the body instead of the downward motion as previously described.

Effect of Varying the Powers.—Select some particular fibre of definite structure amongst those upon the slide. Fix the slide in position on the stage by means of the stage springs and proceed to note the differences in appearance produced by the various eye-pieces and objectives available. For example, observe the appearance of a fibre with the lowest magnifications, and note the increase of size due to elongation of the tube to its full length. Examine the same fibre with higher objectives, observing not only the magnification but also the clearer definition of physical structure.

Mounting Fibres.—It is quite impossible in an elementary treatise of this description to enter fully into the whole subject of the mounting of fibres. Instructions must therefore be limited to those which will enable the student to examine fibres and papers for technical purposes. Taking the case of an ordinary high-class rag paper the student should proceed as follows:

From the sheet of paper cut three or four pieces about a half-inch square, so as to obtain a representative sample. Place the paper in a small porcelain dish with sufficient caustic soda solution (1 per cent. solution will be strong enough) completely to cover the paper. Gently warm the dish with its contents in any convenient manner for about half an hour, in order to dissolve out the gelatine and other sizing ingredients. Remove the pieces of paper from the dish and thoroughly wash them free from caustic soda. Then put the paper in a small bottle together with some glass beads, and nearly fill the bottle with water. Shake the bottle vigorously until the whole of the paper is completely disintegrated into isolated fibres and then strain off the contents of the bottle through a piece of very fine wire gauze or muslin. The water drains away leaving the fibres on the gauze in a condition fit for examination.

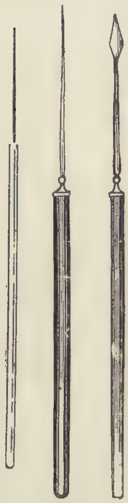


Fig. 135.—Microscope Needles.

With two suitable microscope needles, pick out a few fibres here and there and transfer them to an ordinary glass slip, removing the excess of moisture by pressing the little heap of fibres lightly with a piece of filter paper. Moisten the sample with one or two drops of some microscope reagent, preferably the zinc chloride and iodine solution. Distribute the fibres evenly on the glass by tapping them gently with a glass rod, the end of which has been carefully rounded off.

The distribution of the fibres is a very important matter. The beginner invariably places too large a quantity of pulp on the slide, and renders it almost impossible to make a thorough and adequate examination of the fibres. A small quantity of pulp evenly distributed on the glass, avoiding the aggregation of small masses, gives far better results, as experience will soon prove.

Cover the stained fibres with a circular cover-glass, five-eighths or three-quarters of an inch in diameter, taking care that no air bubbles are imprisoned under the glass. This is most easily effected by holding the cover-glass with a needle in a slanted position on the slide close to the fibres, and lowering the glass gradually down upon the mass of fibres, as in this way the liquid comes into contact with the glass and drives out all the air as the glass is lowered.

Remove any excess of reagent or liquid by what is known as the process of *irrigation*—that is to say, by holding the edge of a piece of filter paper on the slide close up to the cover-glass. The excess liquid is soaked up by the filter paper. Finally, press down the cover-glass gently with the filter paper, so as to bring all the fibres flat down upon the glass.

The fibres thus mounted may be transferred to the microscope and examined.

Examination of New Fibres.—A small quantity of pulp for microscopic examination can readily be obtained from any raw material by the following simple process:

Break up a piece of the material, if necessary, into small pieces. The best method of doing this is to hammer the fibre gently on a block of wood, or a piece of stout iron plate, until it is frayed out into a more or less fibrous condition. Place the disintegrated fibre in a flask or a small saucepan, and cover it with a solution of caustic soda (10 parts of caustic soda in 100 parts water), and boil for about an hour, taking care to make up the loss due to evaporation of the water by adding small quantities of fresh water from time to time. When the fibre is soft, pour off the water through a wire cloth and thoroughly wash the small quantity of fibre. The pulp so obtained can be used for microscopic investigations. If bleached pulp is desired, put the boiled fibre in a solution of chloride of lime, and leave the mixture to stand all night. Drain off the water as before, and thoroughly wash with clean water.

Estimating Percentages of Fibre.—The examination of a paper containing two or more fibrous constituents is a matter which demands considerable experience. It is scarcely possible to determine the proportions present with a degree of accuracy greater than 5 per cent. in normal cases. A sample of paper is broken up and mounted in the usual way, and the proportions of fibres arrived at by one of two methods:

(1) The method of "counting the fibres."

(2) The method of "mental impressions."

In the first case various portions of the slide are brought into the field of view and the fibres counted, due allowance being made for irregularity in length.

In the second case the fibres are not absolutely counted, but a record is made for each field of view examined as to the impression made on the mind of the observer.

The beginner is recommended to make estimates as to the percentages of two fibres present, by using mixtures of known composition, for there is no royal road to success in this work except that of patience and perseverance with mixtures in which the proportions are already known.

Some Simple Exercises.—(A) Select an *antique* paper known to consist of esparto and chemical wood pulp, and disintegrate the paper for examination. As a staining reagent, use zinc chloride and iodine solution.

Notice effect produced on the depth of colour due to the reagent when using the latter in various stages of dilution as follows:

Mount some of the *moist pulp* with one drop of reagent.

Mount some of the pulp, removing the excess of water from the fibres before staining by the process of *irrigation*, that is, by bringing a piece of filter paper into contact with the pulp and allowing the moisture to be absorbed as far as possible; stain with one drop of zinc chloride and iodine solution.

Mount the third slide, using an equal quantity of pulp, removing all the moisture as far as possible by pressing down a piece of filter paper on the fibres. Then add one drop of zinc chloride and iodine reagent and mount as before.

(B) Changing the reagent and using *iodine* solution proceed as follows:

Place equal quantities of fibre on four slides and allow the pulp to dry out in the air. Add one drop of iodine solution to the first slide and cover as usual. To the second add one drop of iodine solution diluted with one drop of water. To the third add one drop of iodine solution diluted with two drops of water. Mount the remaining slides, diluting the iodine solution with water in larger proportions, and finally compare the difference in the intensity of colour.

(C) Make notes as to the physical structure of the esparto and wood pulp

fibres, comparing the notes so made with the description given in chap. xii. Search for all the characteristics of the fibres, and as far as possible make drawings of those examined.

(D) Estimate the proportions of fibres present, going over the whole slide carefully, taking about twenty or thirty readings, in each case adopting the method of "counting the fibres," and the method of "mental impressions."

The Measurement of the Length of Fibres.—The length of fibres is determined by means of the stage micrometer and the eye-piece micrometer, which instruments have already been described.

The millimetre scale is placed on the stage of the microscope in the usual way, and the eye-piece scale placed in the eye-piece. The microscope is then focused clearly, and the divisions of the millimetre scale and eye-piece scale can then be observed together as if in one field. The eye-piece is rotated until its divisions run parallel with the divisions on the millimetre scale, and when this has been done a careful note is made as to the number of millimetres corresponding to the ten divisions of the eye-piece scale. For example:

Divisions on the eye-piece scale, 10·0.
Divisions on the millimetre scale, 0·69.

From this it follows that each whole division on the eye-piece scale is equivalent to ·069 millimetre.

This value is, of course, only true for the conditions under which the readings have been taken, and for the particular combination of eye-piece, objective and tube length concerned. Any alteration in one or more of these affects the values of the eye-piece divisions.

A stage micrometer divided into thousandths of an inch can be used if preferred.

Thus, for example, with one $\frac{1}{2}$-inch objective and a tube length of 10 inches for a particular eye-piece, the value may be

7 divisions, on eye-piece scale = ·483 millimetre.

If the tube length is reduced to 6 inches by being pushed in, then

7 divisions on scale may equal ·770 millimetre.

It is therefore necessary to compile a table, stating clearly the conditions under which the microscope is used, and the value of the scale for all the conditions possible.

TABLE XXVI.—*Of Values for Microscope (Messrs. Watson. Stand H.) Showing the Value of One Whole Division of Eye-piece. Scale in Millimetres.*

Eye-piece.	Objective.	Value of One Eye-piece Division. For 6-inch tube length.	Value of One Eye-piece Division. For 10-inch tube length.
B	$\frac{1}{2}$ inch.	·110 mm.	·069 mm.
	$\frac{1}{6}$ inch.	·038 ,,	·024 ,,
C	$\frac{1}{2}$ inch.	·100 ,,	·064 ,,
	$\frac{1}{6}$ inch.	·034 ,,	·022 ,,

A line of unknown dimensions, equal to 5·6 divisions of the eye-piece scale, when examined with the $\frac{1}{4}$-inch objective, eye-piece C, and the tube racked out to its full length of 10 inches, would be (·022 by 5·6) millimetres, that is, 0·1232 millimetre long.

The apparatus described is obviously very simple in character, and easy to manipulate. A little practice on fibres of known length will soon give the student confidence in his ability to measure other fibres or to determine the extent to which the fibres have been shortened by the process of beating.

This latter determination is a matter of considerable difficulty, however, which requires the measurement of a large number of fairly typical fibres in order to arrive at an approximately accurate average figure. With short fibres, such as straw and grass, the measurement is comparatively easy, but in the case of long fibres, like cotton, linen and hemp, a good deal of judgment is necessary, on account of the great differences in the length of the individual beaten fibres. Comparative readings under suitable conditions will give useful information when carefully taken. Cotton pulp is easier to deal with than hemp, for example, since the beaten fibres are more definite in shape and less liable to produce masses of fibrillæ, which tend to render measurement difficult.

With unbeaten pulp in which the fibres, as a whole, are present in the maximum length, the differences may not be great in the sample under examination, though for certain vegetable species the age of the plant will, to some extent, determine the average length of the ultimate fibre.

Reagents for Microscope Work.

The work of identification of fibres would certainly be much simplified if it were possible to find definite colour reagents, capable of giving colours on the surface of the sheet of paper as in the case of the presence of mechanical wood pulp in a paper, where the use of some special reagent like aniline sulphate, or phloroglucine, is resorted to.

When reagents have been discovered for paper-testing which are as definite in their colour reactions for other fibres, then the work of differentiation will be much simpler. At present the microscope is the only safe means of identification and even then it is frequently impossible completely to analyse the mixture of fibres in a well-beaten paper.

For ordinary purposes the identification of fibres is assisted by means of a solution of iodine.

This reagent usually gives the following results :

(1) *Fibres coloured yellow.*
1. Mechanical wood.
2. Jute.

(2) *Fibres not coloured.*
1. Wood cellulose.
2. Straw cellulose.
3. Esparto cellulose.

(3) *Fibres coloured brown.*
1. Cotton.
2. Linen.
3. Hemp.

Now the effect of any special solution by which the fibres are coloured, is not merely one of coloration. The reagent serves to intensify the differences of structure, and brings out the structural details more clearly.

It is important in microscope work to employ a solution of known strength. Unless this is done variations in the intensity of colour will be observed and these variations are apt to lead to confusion in results.

In using reagents for the examination of fibres under the microscope variations in the colour effects are liable to occur under the following conditions :

(1) The use of reagents of unknown strength. It is advisable always to work with a solution of standard composition, so that results may be readily compared.

(2) The condition of the pulp will, of course, modify the intensity of colour ; if the small quantity of fibre put on the glass slip is very moist it will not take so dense a colour as a similar portion squeezed out fairly dry by means of blotting paper.

(3) The physical condition of the fibres under investigation is an important factor in the colour reaction. The appearance, for example, of cotton fibre will vary according to the treatment it has sustained.

This can be seen by examination of a piece of cotton, first raw, then in a piece of old cotton rag, and again in the same rags after boiling, and, finally, after being thoroughly beaten and ready for making into paper.

(4) The purity of the cellulose itself has also a marked influence upon the colour reactions. The truth of this statement can easily be verified by examination of specimens of imperfectly boiled wood pulp, and samples prepared from over-boiled wood. The structural details are much more marked in the former case.

(5) The length of time during which the fibres are exposed to the influence of the reagent also causes variation in colour. Iodine, especially, is a fugitive reagent, and fibres showing a dense colour at first will gradually lose the colour and eventually appear almost colourless.

The list of solutions in use is as follows :

Taking the case of *iodine* we find the following formulæ in use by various well-known experts :

Winkler.

Potassium iodide	5 grammes.
Iodine	1 ,,
Water	20 c.c.
Glycerine	1 ,,

Behrens.

Water	40 grammes
Iodine	2 ,,
Potassium iodide	10 ,,

Herzberg.

Potassium iodide	2 grammes.
Iodine	1·15 ,,
Water	20 ,,
Glycerine	1 c.c.

The second reagent and one which is exceedingly useful is the *zinc chloride and iodine* solution.

This reagent gives a clear distinct result in many cases, but it is impossible to state that this solution is always to be preferred to iodine. Much depends upon the condition of the beaten pulp.

The following solutions are those usually employed :

Winkler.

Chloride of zinc	40 grammes.
Potassium iodide	5 ,,
Iodine	1 ,,
Water	14 c.c.

Behrens.

Zinc chloride solution (sp. gr. 2·00)	90 grammes.
Water	10 ,,
Potassium iodide	6 ,,
Iodine to saturate this solution.	

Hohnel.

Zinc chloride	30 grammes.
Potassium iodide	5 ,,
Iodine	1 ,,
Water	14 c.c.

These reagents are well known to those accustomed to employ the microscope for the identification of fibres, but there are certain reagents perhaps less well known, which are exceedingly valuable under special circumstances.

Dr. Winkler suggests the employment of magnesium chloride in the place of zinc chloride, using the substance in combination with iodine, according to the following formula:

Magnesium chloride (saturated solution)	50 c.c.
Iodine solution (Winkler's formula)	2·5 ,,

Another useful reaction for identifying fibres, or for intensifying the appearance of the structural details is that in which sulphuric acid acts upon the fibres after they have been stained with the usual iodine solution.

The formulæ for the solutions are as follows:

(A)	Potassium iodide	1 gramme.
	Water	100 c.c.
	Iodine, to saturate (add 2 crystals of iodine to solution).	
(B)	Concentrated glycerine	20 c.c.
	Water	10 ,,
	Add sulphuric acid (1·78 sp. gr.) slowly	30 ,,

The fibre is mounted in iodine solution as usual, and covered. A drop of acid is placed on the slide in close contact with the cover-glass and drawn in by the capillary attraction of a piece of blotting paper held on the slide near the cover-glass on the side opposite the acid. This is explained by Fig. 136.

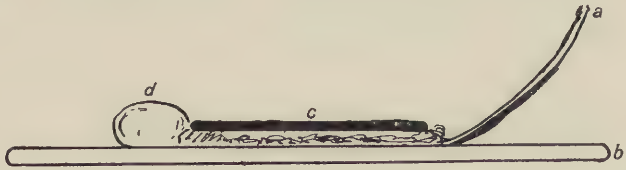


Fig. 136.—Diagram to illustrate Method of staining Fibres by "Irrigation."

a. Piece of blotting paper. *c.* The cover-glass.
b. The glass slip. *d.* Drop of sulphuric acid.

The blotting paper soaks up the liquid under the cover-glass and thereby draws in the drop of sulphuric acid under the cover-glass, and the fibres are stained.

A useful reaction, particularly for lignified fibres and for pulp which has been partially prepared, is that produced by the use of *chlorine water* and a solution of *sodium sulphite*.

The solutions for this test are prepared as follows:

Chlorine water.

Pass chlorine gas into water until the latter is saturated.

Sodium sulphite solution.

Crystallised salt	2 grammes.
Distilled water	40 ,,

The chlorine water acts upon the fibres, producing a slight yellow coloration, and the addition of sodium sulphite to the chlorinated fibre produces a more or less deep magenta colour, which serves to bring out the structural detail more clearly.

Another distinctive test for lignified tissue, particularly wood pulps, is the ferric-ferricyanide reaction, which produces a marked blue coloration in the fibre, due to the formation of prussian blue in the cells of the fibres.

The formulæ as suggested for the reaction by Cross and Bevan are:

(A) Ferric chloride	1·62 grammes.
Distilled water	100 ,,
(B) Potassium ferricyanide	3·3 grammes.
Distilled water	100 ,,

Mix equal volumes of these two solutions when required.

The well-known *phloroglucine* reagent is prepared as follows:

Phloroglucine	4 grammes.
Alcohol	100 c.c.
Hydrochloric acid	50 ,,

The differentiation of various fibres by the use of *aniline dyes* has been fully studied by Professor Behrens.

The more frequently used dyes are magenta, methylene blue, eosin, diphenylamine blue, these solutions being most conveniently prepared with a strength of 1 in 2000.

These dyes act differently with various fibres, and Behrens claims that it is possible to make use of them as a means of identification, when applied under precise and definite conditions. He states that it is possible to obtain very marked differences with similar fibres by means of "combination" results. That is to say, fibres treated with one aniline colour, will subsequently yield marked differences in colour when further treated with a second dye. In the identification of hemp and flax, which usually proves to be a difficult operation, Behrens obtains what he terms a "combination" colour by treating the mixture of fibres with malachite green and then subsequently with benzopurpurin.

The effect of this double combination is that the hemp appears green and the flax appears a brick-red colour.

There is plenty of scope for further investigation into this question of the identification of fibres. Thus, for instance, the close resemblance of cotton and linen fibres in a well-beaten paper makes the task of determining the proportions of cotton and linen an exceedingly difficult one, and it is very much to be questioned whether an analysis made with the microscope can give in precise

terms and figures the correct proportions of cotton and linen in a paper said to be made from rags.

In a case of this kind much experience is necessary in order to arrive at a satisfactory conclusion, although at the same time it is well to bear in mind that an estimate which comes within 10 per cent. is often sufficient for practical purposes.

The only instances in which the identification is of absolute importance is that in which the presence or absence of cotton in a linen paper, or of linen in a cotton paper, for example, might be considered a sufficient excuse for rejecting a delivery of paper, but this is in itself an extremely unlikely case.

TABLE XXVII.—*Micro-chemical Reactions of Fibres.*

Fibres.	Coloration produced.		
	Iodine Solution.	Zinc Chloride, Iodine Solution.	Magnesium Chloride, Iodine Solution.
Cotton, linen, hemp . .	Brown	Wine-red	Reddish brown
Esparto, straw, bamboo celluloses . . .	Grey to greyish brown	Blue to violet, or blue to greyish violet	Bluish violet
Wood celluloses . . .	Colourless	Blue to bluish violet	Light brown to red
Manila hemp . . .	Grey, brown, or yellowish brown	Dark yellow or greenish yellow	Yellow, greenish yellow
Mechanical wood pulp, jute	Yellow	Yellow	Yellow
Unbleached Manila, Straw (partially boiled) . .	Yellow	Yellow	Yellow

CHAPTER XII

FIBROUS MATERIALS USED IN PAPER-MAKING

General classification—Linen, cotton, esparto, straw, hemp, jute, wood pulp, other fibres—Microscopic features—Dimensions—Colour reactions.

Vegetable Fibres.

THE number of vegetable fibrous substances suitable for the manufacture of paper is comparatively small. It is true that in the laboratory paper can be made from plants of every description, but the practical application of such fibres for commercial purposes is determined by the cost of manufacture, the supply of raw material, and the quality of the final product. These latter considerations limit the choice of material in a marked degree.

Fig. 136*a*.—The Fibres of a Magazine Paper, chiefly esparto.

In the library of the British Museum may be seen a Dutch book, printed as far back as 1772, containing over sixty specimens of paper prepared from different materials; but it is merely a curiosity, a facsimile of which could readily be prepared by any one possessing a few simple chemical appliances. Hence, while such widely differing vegetable substances as straw, cotton, linen, hemp, hay, nettle, sugar-cane, wood, cabbage-stalks, cocoanut-matting, grass, peat and many others may be converted into paper of some description, yet the list of fibres actually in common use as raw material for paper-making is a short one.

A broad general classification of paper and paper products, and the raw materials employed in manufacture may be made as follows:

Writings and printings	Rags, esparto, and wood pulp.
Wrappers and boards	Wood, hemp, jute, straw, waste paper.

However varied in form and appearance the ordinary plants suitable for the manufacture of paper may be, yet when subjected to chemical treatment they appear to lose their distinctive form and physical structure, yielding a white

fibrous substance which is called *cellulose*, and it is not easy by mere superficial examination to determine the source of this white cellulose when thus isolated from the plant.

But though similar in appearance and chemical composition, yet the various celluloses may be distinguished by microscopic examination of the ultimate fibre. The microscope at once reveals very important and characteristic differences in structure, and largely explains the great differences to be found in the paper produced. The effect of the processes used for isolating the pure paper-making fibre is confined therefore to the removal of *non-fibrous constituents*, a term which may be conveniently used as comprising all the elements in the plant which have no value as fibre.

A fibrous plant may be regarded as a structure consisting of fibres associated with cells which are built up together to form a tissue more or less complex, according to the nature of the plant and the family to which it belongs. The fibres are associated with the cells somewhat after the fashion of a building in which bricks and mortar are found; but the analogy must not be pushed too far, since the association in the plant is by no means so simple as the mere mechanical contact between bricks and mortar.

The commercial application of the plant itself for the purpose of the paper-maker requires a breaking down of the plant structure into fibres and cells. The valuable portion of the plant is the fibre, but in some cases the cells are also useful.

The classification of the paper-making fibres, or celluloses, from the various available plants can be made when the plant structure is looked at from this point of view.

In *cotton* no separation of fibres from cellular matter is necessary, since the growth of the plant results in the formation of a mass of fibres free from any cells or cellular matter.

In *flax*, *hemp* and *jute* the plant is a typical fibrous mass, in which the individual fibres are more closely associated with one another than with the surrounding cellular matter.

In the case of *straw*, *esparto* and *wood* the fibres are more regularly distributed through the substance, and are more intimately associated with the cellular mass than in the case of flax and hemp.

In the case of *plant seeds*, such as those of the cereals and many vegetables, the cellulose compounds are not fibrous in character, but consist almost entirely of cellular matter, and these substances are therefore of little interest to the paper-maker.

The plants which are of interest to the paper-maker can therefore be arranged under some scheme of classification which commences with the typical cotton fibre characterised by the presence of a very high percentage of fibre, with a complete absence of cellular matter, and which ends up with plant structures containing a large proportion of cellular matter with the absence of useful fibrous constituents.

Considered from the point of view of resistance to chemical treatment the typical paper-making fibres may be roughly classified under two headings.

(1) Those of greatest resistance to the action of chemicals: *cotton*, *flax*, *hemp*, *ramie*, *sunn hemp*, &c., in which the average yield is over 75 per cent. of cellulose.

(2) Those of less resistance to chemical treatment: *esparto*, *straw*, *jute*, *wood*, *bamboo*, &c., in which the average yield is from 40 to 60 per cent. of cellulose.

These striking differences in the nature of the several plants available for the manufacture of paper are sufficient to explain why rag papers come nearest to the ideal paper.

Some rough-and-ready idea of the permanence and durability of papers may

be obtained by submitting samples of papers for eighteen to twenty hours in an oven at a temperature of about 110° C. The colour of a high-class rag-paper will not appreciably alter. A paper made from esparto or straw will turn a light

Fig. 137.—Linen Fibres, according to Herzberg.

1, 2, 3, Natural fibres exhibiting strongly marked features; 4, A fibre flattened out at one end, and resembling cotton; 5, A typical linen fibre after boiling and bleaching; 6, A fibre which appears to be cotton, but can be identified as linen on account of numerous pores.

yellowish brown. An ordinary printing paper containing mechanical wood pulp will take on a decided yellowish brown colour, the changes being due to the condition of the cellulose in the paper.

Rags.—All rags have their peculiarities of quality and suitability, their value

being in proportion to cleanliness, whiteness and strength. The different grades are usually supplied to the paper-mill roughly sorted out according to their condition and colour, as the term "rags" is used in the trade to include all kinds of

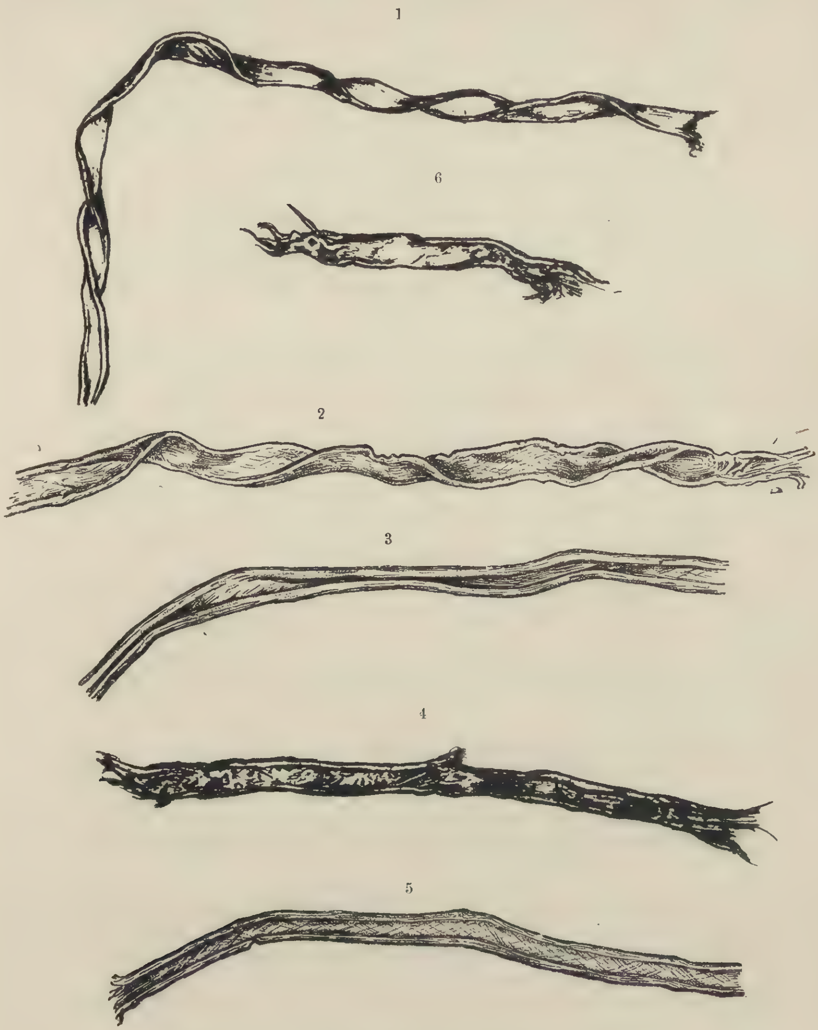


Fig. 138.—Cotton Fibres, according to Herzberg.

1, General appearance of a raw fibre ; 2, Fibre as occasionally seen after boiling ; 3, Fibre after moderate amount of beating, still readily recognised ; 4, 5, Usual appearance of fibres in ordinary rag papers ; 6, Structureless cotton fibre as seen in well-beaten pulp.

textile fabrics which have already been utilised for other purposes. The list of materials which should be mentioned under this heading is a fairly long one:

New linen cuttings, new cotton pieces, fine white linens or cottons, inferior white rags, coloured rags, blue rags, gunny, rope, sailcloth, canvas, hemp and flax waste, manila, bagging.

Cotton and linen rags, sailcloth and canvas are used in the manufacture of high-class hand-made and machine-made writing papers. Rope, gunny, bagging and textile wastes are utilised chiefly for wrappers and boards.

Linen.—For the manufacture of high-class papers the bast cells of flax are regarded as being the most suitable material. The linen fibre in its raw state is readily distinguished from cotton, under the microscope, by a narrow central canal of small diameter, and by the repeated thickening of the cell wall which forms knots in the fibre at regular and frequent intervals. The fibre is also more cylindrical in shape and of smaller diameter, the ends tapering gradually to a fine point.

Many of these distinguishing characteristics are greatly modified in the process of manufacture, so that it often becomes a matter of some difficulty to determine the proportion of cotton and linen in a given paper, while the identification of linen and hemp in a mixture of the two with a view of finding out the relative amounts present is in many cases impossible owing to the strong resemblance of the ultimate beaten fibres.

The application of suitable reagents to the raw fibre when examined under the microscope serves to bring out the details of structure very clearly, but with paper containing the well-boiled and *beaten* material these details are by no means so distinct. The curious brownish colour found with the knots in the raw fibre is almost entirely absent in the beaten stuff and can only be identified with a higher magnification than is usually employed. The fibre ends are generally blunt and frayed out, the pieces cut off being torn into more or less structureless particles. Some fibres are flattened out and resemble cotton.

The identification of linen involves a careful search for the central canal, the traces of knots, and the presence of numerous pores in the cell walls appearing as dark lines across the fibre.

Cotton.—Under the microscope raw cotton presents a characteristic form which is easily recognised. The fibre is a transparent tube, usually flattened and collapsed, always more or less twisted and tapering off to a blunt point. The twisted or corkscrew form of the fibre serves to distinguish it from other vegetable fibres and is an easy means of identifying cotton. The fibre is quite devoid of pores and knots.

The treatment necessary for the conversion of cotton rags into paper alters the general nature and appearance of the fibre considerably. The curious twist in the raw cotton is largely removed by the action of the caustic soda used for boiling the rags, while the mechanical reduction of the fibres by the process of "beating" also affects the physical structure. The natural ends of the fibre are seldom found in paper; the fibres are often flattened to such an extent as to be mistaken for wood cellulose, though in the latter case the coloration produced by the use of zinc chloride and iodine solution serves to identify the wood-cells with certainty; the fibres are sometimes split lengthwise by prolonged beating which gives them a partially striated appearance, somewhat resembling well-beaten hemp; the fibres frequently exhibit, after the process of beating, a complete *absence* of structure, owing to the removal of those characteristic features which distinguish the raw fibre.

Amongst papers containing cotton fibre, ordinary blottings preserve the original structure best, except that the fibres are cut very short, while high-class T.S. writings exhibit the greatest deviations from the original structure, on account of the severe treatment to which the fibre has been subjected.

Esparto.—This fibre was introduced into England in 1852 by Thomas Routledge. It is a grass, *Stipa tenacissima*, growing freely in Spain, Algeria, and other parts of Northern Africa, which has proved to be eminently suitable for magazine papers and soft printings. The leaf grows to a height of three or four

feet, which as it ripens and becomes dry curls up into a circular form, resembling a thick piece of wire.

Although raw esparto differs greatly in appearance and in structure from straw, yet it closely resembles straw when reduced to ultimate fibres by treatment with caustic soda. The fibres of straw and esparto have one peculiarity in common which distinguishes them from other paper-making fibres, viz., the shortness of the isolated cells. For this reason the structure is not altered or modified through the process of beating to any serious extent, so that the fibres in a well-beaten esparto paper still resemble closely the raw isolated fibres from boiled esparto pulp which has not been beaten. The bast cells are short, smooth

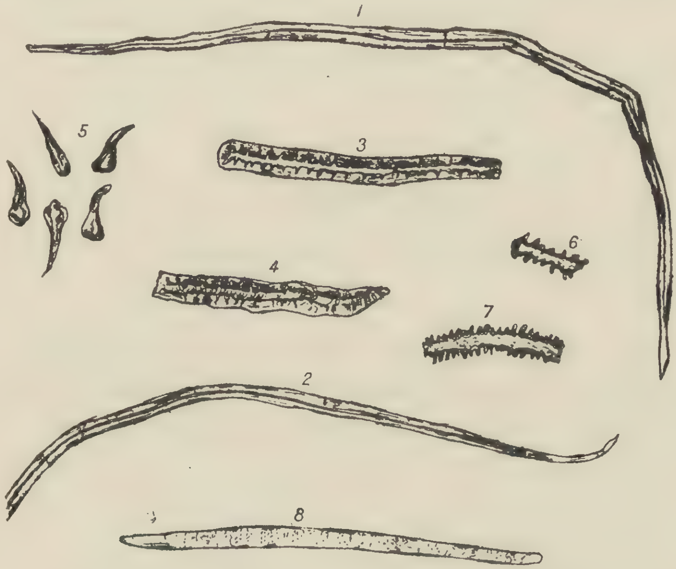


Fig. 139.—Esparto Fibres, according to Herzberg.
1, 2, Bast cells ; 3, 4, Sclerenchyma cells ; 5, Seed hairs ; 6, 7, Epidermal cells (serrated edges) ; 8, Pitted vessel.

fibres, cylindrical in form, tapering off to fine rounded points, having a minute central canal.

In addition to the bast cells, the esparto contains epidermic cells of varying length and of curious shape having serrated edges. The presence also of small pear-shaped vessels, some short and others long, the source of which is to be found in the hairs attached to the surface of the leaf, is a certain indication of esparto.

Straw.—This has been used as a paper-making fibre since 1800. Between the years 1870 to 1890 enormous quantities were utilised for news and cheap printings, but the fibre has now been superseded by wood pulp. A certain quantity is, however, still employed, since it imparts a hardness to common printings which cannot be obtained with wood. The main portion of the straw now used in paper-making is submitted to a very slight chemical treatment, and converted into straw boards.

The bast cells are long, thin fibres of cylindrical form with a small central canal, not clearly discernible with low powers. The cells when bent, which they often are, as examined under the microscope, do not assume a graceful curved form like esparto, but usually kink at the bends as a rubber tube will when folded

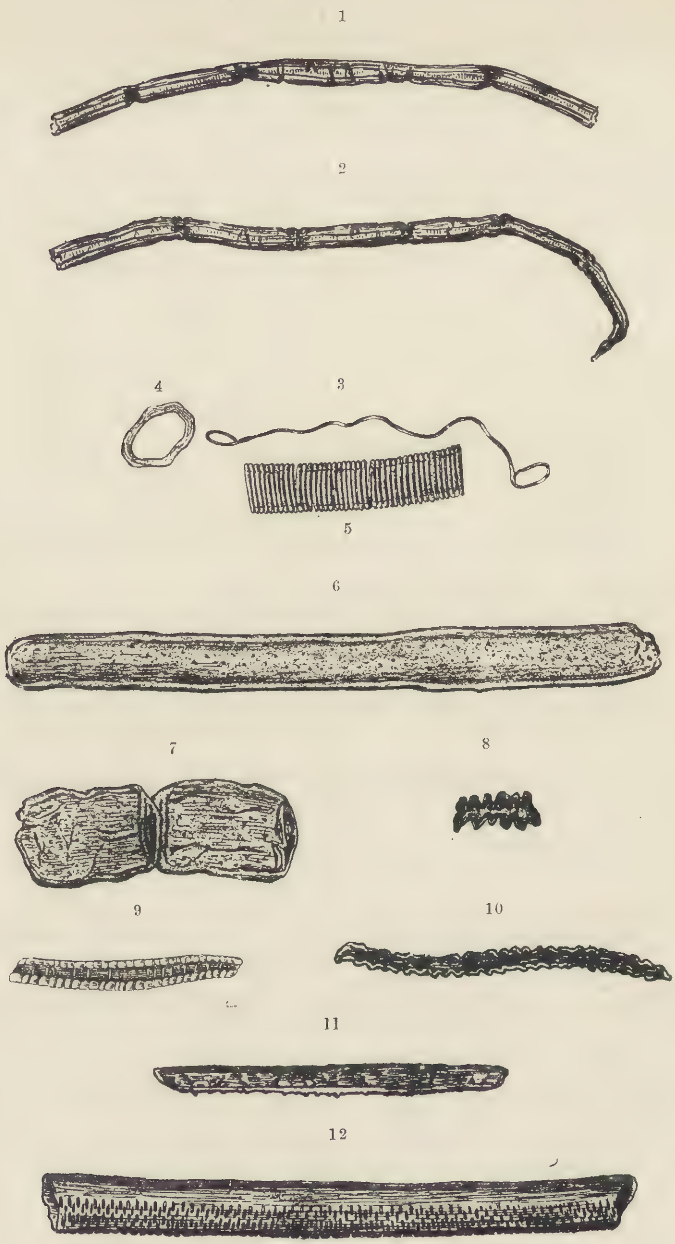


Fig. 140.—Straw Fibre, according to Herzberg.

1, 2, Bast cells; 3, 4, 5, Spiral vessels; 6, 7, Parenchyma cells; 8, 10, 11, Epidermal cells; 9, Sclerenchyma cells; 12, Pitted vessel.

sharply. The cells are slightly thickened at intervals, not externally, but internally, giving the central canal a varying diameter. Judicious colouring with the microscopic reagents gives a clearly defined structure.

In addition to the bast cells, the straw is recognised by the presence of parenchyma cells, which are specially characteristic of straw. These vary in size, being cylindrical yet somewhat flattened and of different lengths, and usually covered with small pores.

The epidermic cells are of all sizes, having deeply or slightly serrated edges similar to those of esparto, from which it is not easy to distinguish them. Usually the esparto serrated cells are more uniform in shape and size, while the straw cells are very irregular, particularly if the straw is a mixture of various sorts, such as wheat, rye, barley, and oats. The straw may be still further identified by the short, broad, oval-shaped cells found in the pith adhering to the interior portion of the plant stem. The cells of the different straws vary in shape and size, but possess certain general characteristics of the nature described.

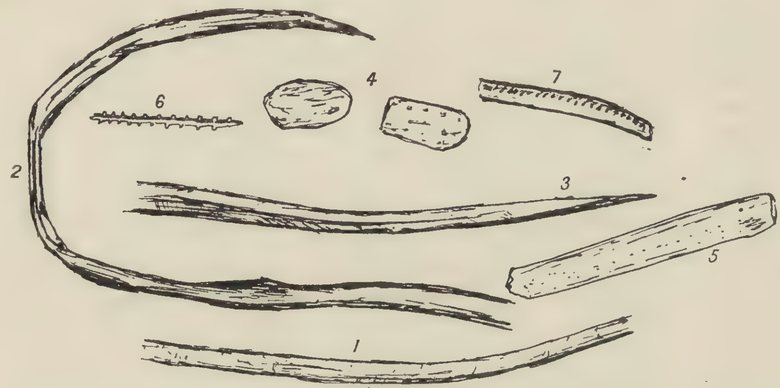


Fig. 141.—Chinese Rice Straw. Fibres closely resemble ordinary wheat straw.
1, 2, Bast cells, of varying diameters; 3, End of bast cell, very pointed; 4, 5, Parenchyma cells; 6, Epidermal cell; 7, Pitted vessel.

Hemp.—A fibre characterised by its great strength. The paper-maker uses hemp in the form of canvas, sail-cloth, rope, and spinning refuse, all of which can be worked up. The material cannot be bleached to a high degree of whiteness, but its strength renders it suitable for the production of banknote and ledger papers, and it is used very largely in conjunction with rags for this purpose. When partially boiled, it is converted into browns and wrappers, being also used for cable insulation purposes.

The term "hemp" covers a variety of plants.

Hemp. *Cannabis sativa.*—Species obtained from Russia, Mauritius, and various parts of India.

Manila hemp. *Musa textilis.*—Found principally in the Philippine Islands.

Sunn hemp. *Crotolaria juncea.*—Found in India and known sometimes as Bombay or Madras hemp.

The hemp fibre resembles linen very closely. In the raw state certain differences in structure serve for the purpose of identification, such as the striations parallel to the length of the fibre, fine transverse markings across the surface, broad flattened ends, sometimes fork-shaped, and small projecting hairs at some of the joints.

These differences cannot be relied upon with certainty when the fibre has been converted into paper, for they become so modified and altered that identification is extremely difficult. A well-beaten hemp paper will exhibit a large number of fibrillæ or small fibres produced from the hemp by continued beating, which, when treated with the ordinary zinc chloride and iodine solution, will remain almost colourless. A similarly beaten linen paper will not show this peculiarity to the same extent.

To distinguish an all-linen paper from an all-hemp paper is not such a difficult matter, but the determination of the quantity of linen in a ledger or deed paper made from a mixture of linen cuttings and canvas is in many cases almost impossible.

Fig. 142.—1–5, Hemp fibres (Herzberg); 6, Ends of Hemp fibres highly magnified.

Manila Hemp.—Closely resembles jute, not only as it appears after the beating necessary for the production of paper, but also in the raw state. The fibres are somewhat larger in diameter, and the cell walls are marked with pores, which, however, do not show very distinctly. A paper containing manila hemp is distinguished by occasional groups of small narrow cells with semicircular ends which are not found in jute. The central canal is not quite so varying in diameter as in the case of jute.

The ultimate fibre is much shorter than in the true hemp; the canal being more distinct.

Jute.—A material resembling hemp in general appearance, which is worked up by the textile manufacturers into cloth and bagging, which eventually find their way into the paper-mill. It is frequently found mixed with hemp in inferior qualities of rope and canvas.

The jute fibre is seldom used in white papers, being usually employed for

browns and wrappers. The raw fibre is chiefly recognised by the very irregular shape and varying diameter of the central canal, which will be broad in some places and very thin in others. The fibres also frequently occur in bundles or filaments, which, however, are found separated in bleached stuff. The presence of knots is also characteristic of the jute fibre, and these are easily seen when the zinc chloride and iodine solution is applied. Jute is frequently found in papers supposed to be made entirely of hemp, owing to the fact that the canvas and rope used is often adulterated with jute. The presence of jute in such cases cannot be attributed to a deliberate addition of the material by the paper-maker

Fig. 143.—Jute fibres (Herzberg).

for the purpose of adulteration, as he may be quite ignorant of its existence in the raw fibres.

Wood Pulp.—The introduction of paper-making fibre manufactured from wood dates from 1846, when Keller brought out a process for the manufacture of *mechanical* wood pulp. In 1866 Tilghmann patented a method for the production of *chemical* wood pulp, and since that date the consumption of this material has reached an enormous figure. The chemical pulp is used in all kinds of paper, either by itself or in conjunction with other fibres, but mechanical wood is only suitable for cheap printings and boards.

The trees which furnish the best wood for this purpose are the *Coniferæ*, such as the common spruce and silver fir found in Europe, and the black spruce, white spruce, and American pine of the United States and Canada. Generally speaking, all soft woods, such as spruce, pine, fir, aspen, balsam, poplar, cottonwood, are suitable for wood pulp; the hard woods, such as mahogany, hemlock,

beech, birch and maple, being difficult to treat, and yielding a pulp of inferior quality and colour.

The cells or elements which form the woody tissue of plants are varied in shape and size. The complex structure of the plant stem is due to the association of true woody fibres with tracheids, or pitted cells, and medullary tissue. In the *Coniferæ*, or cone-bearing trees, the wood is made up entirely of tracheids,

Fig. 144.—Spruce Wood Fibre, according to Herzberg.

which cells are easily recognised in spruce. With poplar, the elements are true woody fibres, or libriform cells, which present an entirely different appearance.

Chemical Wood Pulp.—The treatment to which wood is submitted for the preparation of chemical pulp isolates the cells from one another in such a manner as to give them their maximum length and true form. The markings on the cells vary in character according to the particular wood, so that it is possible, by careful observation of the cells under the microscope, to identify the wood from which the pulp has been made.

Spruce.—The fibres of spruce are most easily recognised by their characteristic flat ribbon-like shape and the existence of circular pitted vessels, or pores, in the fibres. The circular markings are usually prominent in hard strong sulphites, but they are often less distinct in well-boiled pulps.

Occasionally cells assume the twisted shape peculiar to cotton, but they can be differentiated by the zinc chloride and iodine solution, which imparts a bluish colour, whereas cotton is coloured brown.

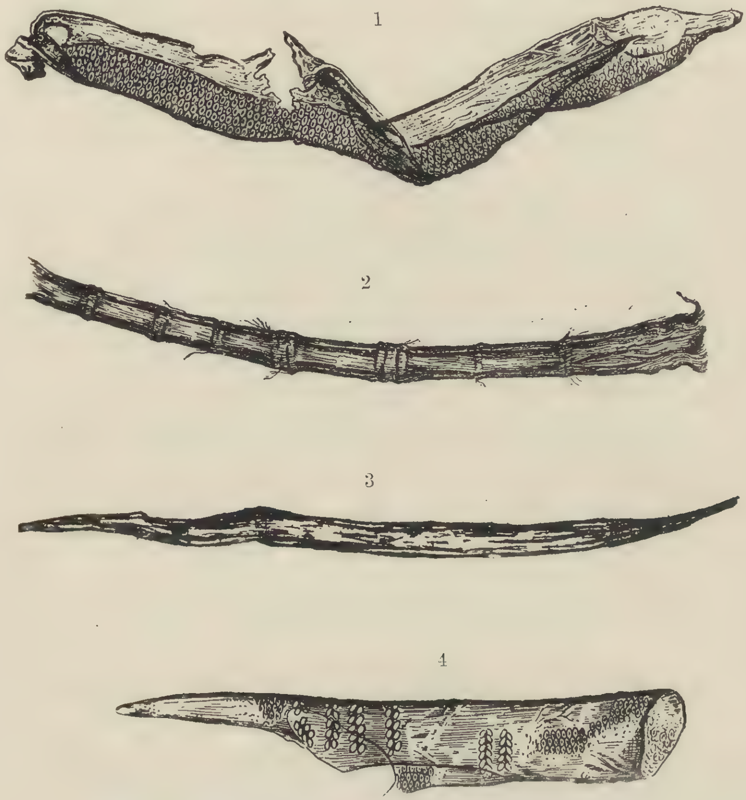


Fig. 145.—Poplar Wood Fibre (Herzberg).

The shape and distribution of the pores in the fibres afford some indication of the particular tree employed. For example, *Pinus picea* is characterised by minute pores grouped in series of four, and *Pinus sylvestris* by large egg-shaped pores distributed along the fibres at fairly regular intervals.

Poplar.—The pulp of poplar and similar non-resinous woods is different from that of the conifers spruce and pine. These fibres are shorter and more cylindrical in shape and frequently characterised by knots in the cell wall which give them the appearance of linen. In addition to the true fibres the pulp contains a large proportion of curiously shaped cells, the markings of which are most distinctive.

Birch contains a greater number of such cells than poplar.

Birch.—Birch fibres somewhat resemble straw, more particularly those straw

fibres having thick walls. The pores are small and oval-shaped. The ends of the fibres are too variable in shape to be considered distinctive.

Fig. 146.—Birch Wood Fibre (Herzberg).

The cells are very characteristic, being large, broad, and pointed, marked with narrow pores lying across the cells in great number.

Mechanical Wood Pulp.—The drastic treatment in the mechanical process by which the pulp is manufactured results in the formation of a mass of fibres and fibrous elements possessing little "felting" power. The pulp consists of a mixture of structureless particles and fibres still preserving the characteristic

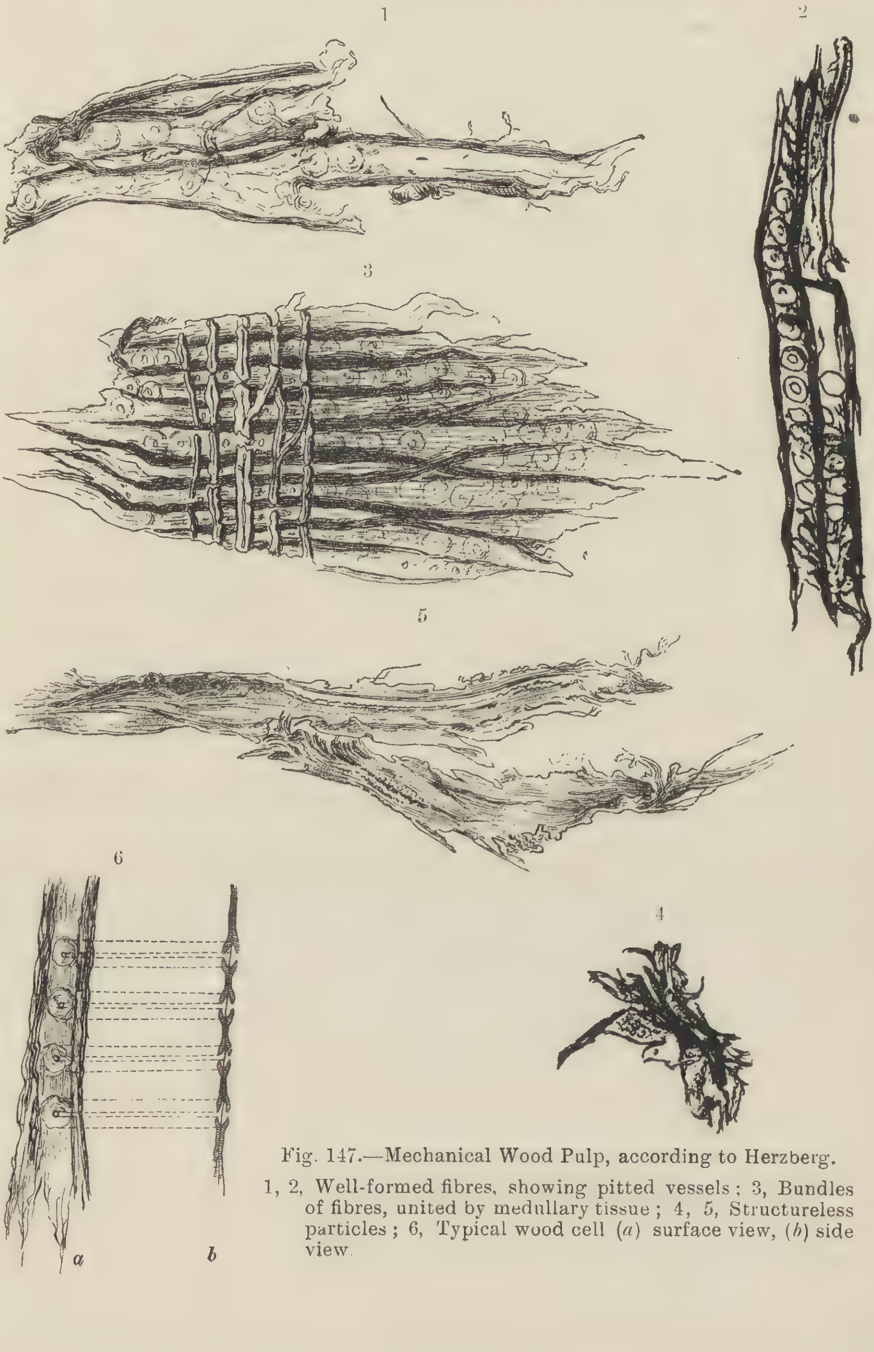


Fig. 147.—Mechanical Wood Pulp, according to Herzberg.

1, 2, Well-formed fibres, showing pitted vessels; 3, Bundles of fibres, united by medullary tissue; 4, 5, Structureless particles; 6, Typical wood cell (*a*) surface view, (*b*) side view.

features which serve for identification. The structure of the latter can be observed, and the exact form of the cells, pitted vessels, and medullary rays determined, so that the particular class of wood from which the pulp has been prepared can generally be distinguished.

The mechanical wood is not only easily recognised by the structure, but is more readily detected by the deep yellow colour imparted to it by iodine, or by zinc chloride and iodine solution. Other lignified fibres such as jute are coloured in a similar manner, but cannot be confused with ground wood on account of the great difference in structure.

Other Fibres.—Many other fibres are suitable for the manufacture of paper, but up to the present time the utilization of plants other than those

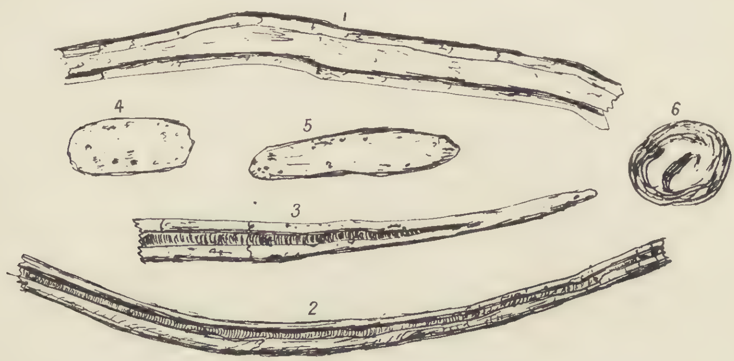


Fig. 148.—Bamboo.

1, 2, Bast cells; 3, Point of a bast cell; 4, 5, Cuticular cells; 6, Pithy matter.

already described has never been carried much beyond the experimental stage. Amongst them may be mentioned:

Adansonia.—This is the inner bark of the Baobab tree (*Adansonia digitata*). It is capable of giving a strong paper and was tried some few years ago in England.

Agave.—The *Aloe* plant, used mainly for cordage. Fibres long and stiff.

Bagasse.—The crushed stalk of the sugar-cane. Easily converted into pulp, but giving a low yield of pulp. Can only be handled profitably where grown.

Bamboo (*Bambusa vulgaris*).—This plant gives excellent pulp, as shown by Mr. Thomas Routledge in 1875. The pulp resembles straw in some respects, consisting of thick walled bast fibres and numerous serrated and ovoid cells.

China grass (*Rhea, Boehmeria nivea*).—A shrub which yields bast fibres from the bark. The ultimate fibre is long, in some cases reaching to eight inches.

Cocoanut fibre (*Cocos nucifera*).—Obtained from the cocoanut husk. Merely of experimental interest.

Munj.—A grass largely used in Indian paper-mills.

New Zealand flax (*Phormium tenax*).—A strong fibre, but little used.

Paper mulberry (*Broussonetia papyrifera*).—A fibre largely used in Burma, Japan and China, specially suited for the papers characteristic of Japan, &c.

Peat.—Used in limited quantities for cheap common brown papers.

Sunn hemp (*Crotolaria juncea*).—A strong fibre used in India for the manufacture of rope and matting.

Animal Fibres.

Animal fibres, such as wool and silk, do not constitute raw material for paper-making. Wool is used for certain mottled papers in limited quantity, and silk is occasionally introduced in the form of thin threads into safety cheque papers. These fibres are easily detected by their peculiar form.

Fig. 149.—Silk Fibres.

a, Ordinary raw silk ; *b*, Tussah silk.

Fig. 150.—Wool Fibres.

a, Scales undeveloped ;
b, Scales well-defined.

Table XXVIII.—*Relative Sizes of Fibres.*

Fibres.	Average. Length. (mm.)	Average. Diameter. (mm.)	Number of fibres placed end to end to equal one inch (approximately).	Number of fibres placed side by side to equal one inch (approximately).
Cotton . . .	30	·025	1	1000
Linen . . .	27	·02	1	1270
Hemp . . .	22	·022	1·25	1150
Sunn hemp . .	7	·03	3·5	840
Ramie . . .	150	·05	0·2	500
Jute . . .	2	·022	12	1270
Esparto . . .	1·5	·012	17	2110
Straw fibres . .	1·8	·015	14	1700
Straw cells . .	0·35	·020	72	1270
Manila hemp . .	6	·024	4	1000
New Zealand flax .	6	·016	4	1600
Bamboo . . .	4	·015	6	1700

Note.—All fibres exhibit variations from the *average* dimensions given.

Colour Reactions of Fibres.—The identification of fibres by means of reagents applied to the surface of the paper is practically limited to the detection of mechanical wood, esparto, or straw. The reagents are aniline sulphate and phloroglucine.

Aniline sulphate is prepared by dissolving 4 parts of the crystallised salt in 100 parts of distilled water. Paper containing mechanical wood is stained yellow, more or less intense according to the amount of mechanical wood present.

Paper containing esparto when gently warmed with a mixture of 10 parts of water and 1 part of aniline test solution turns a rose-red pink, the depth of colour being a rough measure of the amount of esparto.

Straw cellulose gives a similar colour reaction with aniline sulphate.

Phloroglucine is prepared by dissolving 4 parts of the crystalline salt in 100 parts of absolute alcohol and adding 50 parts of pure hydrochloric acid.

This solution produces a reddish stain on papers containing mechanical wood, the depth of colour being a measure of the amount of wood present.

In papers dyed with certain aniline colours, metanil yellow for example, this red coloration will be developed even in the complete absence of mechanical wood. It is, due, however, to the free hydrochloric acid in the reagent. If a paper gives a red colour with a few drops of hydrochloric acid, then some such dye is present. If the paper does not give a red colour with phloroglucine, mechanical wood is absent.

If the paper turns red, mechanical wood may be present. The colour gradually develops and darkens slowly. Coarser particles of wood become deeply stained and give the effect of an uneven coloured surface.

If the paper turns red, and the colour develops suddenly, producing a uniform shade with an absence of deeply stained particles, mechanical wood may not be present. In this case a few drops of hydrochloric acid, *per se*, will stain the paper red.

The identification of fibres is more completely determined by reference to the microscope. In such cases the structure of the fibres may be rendered more definite by the use of certain staining reagents, as shown in Table XXVII., page 155.

CHAPTER XIII

ANALYSIS OF A SHEET OF PAPER

TYPICAL EXAMPLE OF A REPORT ON THE INVESTIGATION OF TWO HIGH-CLASS RAG PAPERS.

THE extent to which a paper is examined for quality and value depends very largely upon the nature of the information required. In the majority of cases the information sought refers to some comparatively simple constituent which is readily determined, or to some single defect which may be of great importance. Thus it may be necessary to report that the sample has a certain breaking strain, a factor easily expressed in simple numerical terms; or to determine accurately the nature of some defect, such as, for example, whether certain coarse fibres appearing in a sheet of news are derived from the pulp used in manufacture, or from odd pieces of string.

Questions of the latter type are exceedingly varied in character, and are furthermore of the greatest importance, since the critical examination of the difficulty fixes the responsibility for any claim for damages.

Of less frequent occurrence are investigations of a complete character, involving a careful measurement of all the normal qualities, physical and chemical, of the paper.

As a typical example of such an investigation the following report will afford some insight into the work required. It is obvious that a complete report must take into account (1) General characteristics, and (2) Special qualities in reference to the purpose for which the paper is to be used.

TABLE XXIX.—**Report.**

This report deals with an investigation into the qualities of two high-class rag papers.

The results are summarised in the table on page 174, the details being separately recorded.

General Conclusion.—The results of this investigation show that paper A is of better quality than paper B, having regard to the purpose for which the papers are intended.

Samples submitted.

The samples consisted of sheets marked respectively:

A. $17\frac{1}{2}$ inches by $22\frac{1}{2}$ (480 sheets) 25 lbs.
B. $17\frac{1}{2}$ „ „ $22\frac{1}{2}$ (480 sheets) 26 „

two sheets of each mark being supplied.

SUMMARY OF RESULTS.

Description.	Paper A.	Paper B.
Weight of ream (480 sheets) 17½″ by 22½″	25·5 lbs.	28·2 lbs.
Thickness of ream (inches) . . .	1·78	1·81
Bursting strain (lbs. per square inch) .	79·0 lbs.	69·0 lbs.
Tensile strength (lbs.) strip 5″ by 1″ .	42·1	30·6
Breaking length (yards) . . .	8727 yards	5743 yards
Crumpling test (number of holes) .	2	65
Folding test (loss of strength) . .	50·0 per cent.	60·0 per cent.
Elasticity : Permanent stretch per cent. Temporary ,, ,,	3·8 4·1	6·3 4·6
Composition by volume : Fibre per cent. . . Gelatine ,, . . Ash ,, . . Air space ,, . .	 59·3 7·2 0·4 33·1	 67·3 4·5 0·6 27·6
Chemical constituents (per cent. by weight) : Moisture . . . Ash . . . . Gelatine . . . Rosin . . . Colouring-matter . . Starch . . . . Acidity	7·5 1·0 9·7 Nil Prussian blue (traces) Traces Nil	7·7 1·0 6·0 Nil Prussian blue (traces) Traces Nil
Fibrous constituents	About 85 per cent. cotton, the remainder being a mixture of fibres too much beaten to be identified with certainty as to linen or cotton	70–80 per cent. cotton with mixture of linen and traces of hemp
Opacity (taking A as 100) . . .	100	80
General appearance, &c. . . .	White colour, well finished, clear, regular "look through," free from dirt	Similar to A, but colour more inclined to a red shade

Weight and Substance.

TABLE XXX.

	Weight of Ream (lbs.) (480 sheets). $17\frac{1}{2}$ inches by $22\frac{1}{2}$.	Thickness of one Sheet. Inches.	Thickness of Ream. Inches.
A.	25·6	·00370	1·77
	25·4	·00372	1·79
	Mean 25·5	·00371	1·78
B.	28·3	·00379	1·82
	28·1	·00377	1·80
	Mean 28·2	·00378	1·81

Bursting Strain. Determined on a diaphragm machine.

	Lbs. per square inch.			Mean.
A.	78·0	80·0	79·0	79·0 lbs.
B.	69·0	67·0	71·0	69·0 ,,

Strength and Stretch.—Strength determined on strips 1 inch by 5 inches. Stretch expressed in terms of the percentage of length.

TABLE XXXI.

Paper.	Direction (*a*).		Direction (*b*).		Mean.	
	Strength.	Stretch.	Strength.	Stretch.	Strength.	Stretch.
	lbs.	per cent.	lbs.	per cent.	lbs.	per cent.
A.	36·0	9·0	48·0	6·2		
	36·5	9·0	49·0	5·7		
	33·0	9·0	52·0	6·8		
	35·0	9·0	51·0	7·8		
	32·0	8·0	51·0	7·8		
	33·0	8·2	49·0	7·8		
	34·2	8·7	50·0	7·0	42·1	7·9
B.	24·0	13·5	34·0	8·0		
	24·5	13·0	43·0	9·0		
	27·0	14·0	43·0	10·0		
	24·0	13·0	32·0	7·8		
	22·0	12·0	37·0	9·4		
	23·0	12·5	34·5	8·0		
	24·0	13·0	37·2	8·8	30·6	10·9

Breaking Length.—The strength expressed in terms of the length of paper which, if suspended, would break of its own weight, is:

TABLE XXXII.

Paper.	Weight of strip 5″ by 1″ in lbs.	Strength of strip in lbs.	Breaking length in yards.
A.	·00067	42·1	8727
B.	·00074	30·6	5743

Elasticity of the Papers.

A record was made of the behaviour of the paper when submitted to tension, as to the nature of the stretch.

TABLE XXXIII.

Paper.	Total Stretch.	Permanent Stretch.	Temporary Stretch.
	per cent.	per cent.	per cent.
A.	7·9	3 8	4·1
B.	10·9	6·3	4·6

Crumpling Test.

TABLE XXXIV.

Number of Trials.	Holes found in A.	Holes found in B.
0	0	0
20	0	2
40	0	3
50	0	7
60	0	12
70	0	20
80	1	29
110	1	56
120	2	65

Folding Test.

Loss of strength due to repeated folding (150 times):

TABLE XXXV.

	Original Strength.	Strength after Folding.	Loss of Strength.
	lbs.	lbs.	per cent.
A.	42·1	21·0	50·0
B.	30·6	12·2	60·0

Composition by Volume.

The composition of the paper in terms of the total volume occupied by the several ingredients as a measure of bulk and density is as follows:

TABLE XXXVI.

	Paper A.	Paper B.
Fibre	59·3	67·3
Gelatine	7·2	4·5
Ash	0·4	0·6
Air space	33·1	27·6
	100·0	100·0

Opacity.

The relative opacities, taking paper A as 100, are:

A. 100
B. 80

A is slightly more opaque than B.

Chemical Constituents.

TABLE XXXVII.

	Paper A.	Paper B.
Moisture	7·5	7·7
Ash	1·0	1·0
Gelatine	9·7	6.0
Colouring-matter	Prussian Blue.	Prussian Blue.
Acidity	Nil.	Nil.

Sizing Qualities.

Both papers well sized. Penetration by ink, nil.

Spread of ink on surface of paper after scratching with a penknife very slight in both cases.

Starch.

Paper A contains more starch than paper B, the amount in both cases being small.

Fibrous Composition.

A. About 85 per cent. cotton, the remainder being a mixture of fibres too much beaten to be identified with certainty as to cotton or linen.

B. About 70 to 80 per cent. cotton, the remainder a confused mixture of linen and hemp.

CHAPTER XIV

THE C.B.S. UNITS

A study of the qualities of paper in terms of the "volume composition"—The expression of the strength of paper in terms of the "breaking weight per unit of sectional area"—The alterations in physical qualities occurring at various stages of manufacture.

Volume Composition.—Many interesting and important points relating to some physical qualities of paper arise out of a consideration of the *volume composition* of a paper as distinct from its composition by weight.*

In the general analysis of a paper dealing with its composition by weight, and with a simple determination of the more important constituents, it is usual to show the proportions by weight, of the fibre, mineral matter, gelatine, rosin, and pigments.

In an imaginary case the analysis might show :

TABLE XXXVIII.

	Per cent.
Moisture	9
Fibre	70
Ash	15
Gelatine	5
Rosin	1
Colouring-matter	Traces
	100

Some one or more of these ingredients may be absent. In special cases examination for sundry impurities may be necessary, but in ordinary paper the above analysis answers the purpose.

Now each of the ingredients occupies a certain volume in the paper. A sheet definite size, however thin it may be, possesses volume, and this depends on the three usual dimensions, length, breadth, and thickness.

$$\text{Volume } (v) = l \times b \times t.$$

In the case of a tub-sized paper, the conditions may be shown clearly by means of Fig. 151, which is a conventional diagram of the paper on an enlarged scale. The gelatine occupies a proportion of the total space as indicated by the letters $g\ g$. Of course the gelatine is diffused through the paper much more than the diagram would appear to indicate.

* See "The C.B.S. Units, or Standards in Paper-testing," by Messrs. Cross and Bevan, Beadle and Sindall.

The fibres may be represented conventionally by the lines crossing and re-crossing one another as shown at *f f*, &c.

The ash may be indicated by circular particles as at *m m*.

The remainder of the total volume, when all the volumes occupied by the several ingredients have been calculated, must be air spaces, and the volume of air space is determined by difference.

The "volume composition" of a paper might be, for example:

	Percentage by volume.
Gelatine	4
Fibre, air-dry . . .	37
Ash	6
Air space	53
	100

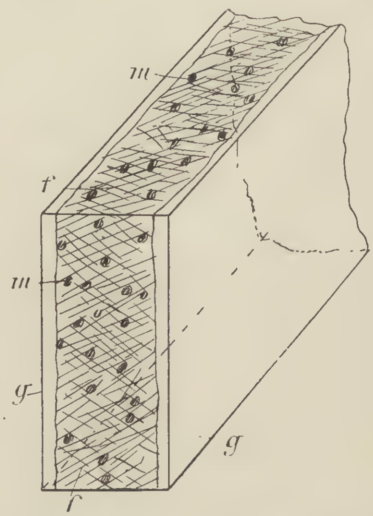


Fig. 151.—Conventional Diagram of a Sheet of Tub-sized Paper.

g, Gelatine ; *f*, Fibres ; *m*, Mineral matter.

The determination of the *volume composition* of a paper is based upon a few simple experimental observations of the following order:

(1) Weight (w) of a circular disc of the paper, in grammes, having an area of exactly 1000 square millimetres.
(2) Thickness (t) of the paper in millimetres.
(3) Percentage of ash in the paper (m).
(4) Percentage of gelatine (g) or of rosin (r).

The case may be clearly stated by means of an actual example.

Paper.—A tub-sized writing, substance 20″ by 30″ (480 sheets) 63 lbs.

Experimental Observations.

(1) Weight of 10 discs having a total area of 10,000 square millimetres.

This was determined by folding the paper several times, and cutting out 10 discs with a circular steel punch of the diameter necessary to give the required area, the object in taking 10 discs being to get an average reading.

10 discs weighed 1·5655 grammes.

(2) Thickness of the 10 discs in millimetres.

Determined by means of the micrometer gauge.

Thickness of 10 discs = 1·60 millimetres.

(3) Percentage of gelatine, found by analysis in the usual way.

Gelatine 5·0 per cent.

(4) Percentage of ash, China clay, found by ordinary methods.

Ash 15·0 per cent.

Now the percentage composition of this paper by weight was:

Air-dry fibre	80·0
Ash	15·0
Gelatine	5·0
	100·0

The volume of a disc of paper measuring 1000 square millimetres in area is expressed at once in cubic centimetres by the thickness of the paper in millimetres.

$$\begin{aligned} \text{Volume } (v) &= \text{area} \times \text{thickness } (t), \\ &= 1000\ t \text{ cubic millimetres}, \\ &= t \text{ cubic centimetres.} \end{aligned}$$

Weight and volume.—Hence the thickness (t) of 10 discs also expresses the volume (v) of the 10 discs.

Volume of 10 discs $= t = 1{\cdot}60$ cubic centimetres.

1·60 c.c. of the paper weighs 1·5655 grammes.

Of this weight, Fibre	is 80 per cent.,	namely	1·2524 grammes.
Ash	,, 15 ,,	,,	0·2348 ,,
Gelatine	,, 5 ,,	,,	0·0783 ,,
			1·5655 grammes.

From this it follows that 1 cc. of the paper contains:

Fibre	0·783 grammes.
Ash	0·147 ,,
Gelatine . . .	0·049 ,,
Total .	0·979 grammes.

The exact volume occupied by these amounts of ash, gelatine or fibre is calculated by making use of the known specific gravities.

The specific gravity (s) of any substance is weight (w) divided by volume (v) and the required volumes are thus readily determined by dividing the weights of the several ingredients by their respective specific gravities.

The specific gravities of the various ingredients are:

Cellulose	1·5
Ash	2·5
Gelatine	1·35

Since weight divided by volume is specific gravity, the volumes occupied by the respective amounts of fibre, gelatine, and ash are:

·783 gramme Fibre = (·783 ÷ 1·5) c.c. . .	= ·522 c.c.
·147 gramme Ash = (·147 ÷ 2·5) c.c. . .	= ·059 ,,
·049 gramme Gelatine = (·049 ÷ 1·35) c.c. .	= ·036 ,,
Balance = Air-space . .	= ·383 ,,
	1·0 c.c.

The percentage Volume Composition is therefore:

Fibre	52·2
Ash	5·9
Gelatine	3·6
Air-space	38·3
	100·0

Apparent Specific Gravity.—The calculation of the *volume composition* of a paper under the system discussed in the "C.B.S. Units" throws considerable light upon the exact relation between the weight of a paper and its volume. This relation is, of course, the *apparent specific gravity* of the paper since

Sp. Gr. = Weight ÷ Volume.

In the case already quoted,

1·60 c.c. of the paper weighs 1·5655 grammes,

in which

1·00 c.c. of the paper weighs 0·979 gramme.

In other words, the weight of 1 c.c. of a paper expresses its "apparent specific gravity," a definite function which is of the greatest importance.

Breaking Weight per Unit of Sectional Area.—Another property of paper which demands attention in the consideration of volume composition relates to the strength of paper.

Usually the strength of a paper is recorded in terms of the number of pounds required to fracture a strip of given width, though in Germany the convenient expression of "breaking length," *i.e.*, the length of paper which, if suspended, would break of its own weight, is almost exclusively employed.

The authors of the pamphlet "The C.B.S. Units" have shown that the following intimate relation exists between the terms—breaking length (l) and apparent specific gravity (s).

$$l \times s = \text{Breaking weight per unit of sectional area.}$$

This third expression is a property of the paper which has not been studied to any great extent. The breaking weight per unit of sectional area is a familiar expression for recording the strength of structural materials, such as brass, iron and wood; but it is usually determined by direct experiments in which a bar of definite sectional area is fractured. The same method can be applied to paper, and the breaking weight per unit of sectional area as found by direct experiment agrees with the figure obtained by finding the product of *breaking length* multiplied by *apparent specific gravity*.

These various relations have an important bearing upon the quality of paper.

The C.B.S. Units applied to a Special Case.

Samples taken.—The author, during a course of lectures given at the Dickinson Institute, Croxley, under the auspices of the Hertfordshire County Council, endeavoured to explain the nature of the volume composition of paper, and the possibilities which might arise from a further study of the physical qualities of paper, by using as an illustration samples of some given paper taken from a machine at certain stages during manufacture, so that the alterations in physical qualities could be properly measured and the influence of successive operations determined.

The samples taken were as follows:

No. 1. Paper from between the couch-rolls and press-rolls.
No. 2. Paper between press-rolls and drying cylinders.
No. 3. Rough machine-finished paper after leaving cylinders.
No. 4. Rough M.F. paper lightly glazed, not tub-sized.
No. 5. ,, ,, ,, heavily glazed, not tub-sized.
No. 6. ,, ,, ,, tub-sized, not glazed.
No. 7. ,, ,, ,, lightly glazed after sizing.
No. 8. ,, ,, ,, heavily glazed after sizing.

These samples fairly represented the various stages in the manufacture of the paper. The paper taken from the couch-rolls was allowed to dry out naturally between blotting paper. The paper taken from the press-rolls was similarly treated. The remaining samples were all taken as rough machine-finished paper and submitted to the processes referred to.

The special investigations made with this paper are interesting in view of the changes in physical condition brought about during manufacture, particularly those relating to bulk and weight.

These changes are set out in Table XXXIX., which shows the weight per ream and thickness per ream at the various stages. The figures are instructive because they show the comparative weights for equal bulk, and the extra number of sheets required to make up the maximum bulk, so that the influence of each operation is clearly shown and measured.

Observations made.—The actual observations were those of

(1) Weight.—Weighed pieces, each having an area of 10,000 square millimetres. Recorded mean weight.

(2) Thickness.—Took an average of independent readings on 1, 5 and 10 pieces respectively.

(3) Ash.—By usual methods.

(4) Gelatine.—By usual methods.

The figures given in Table XXXIX. have been calculated from the observations made.

TABLE XXXIX.

No.	Description.	Weight per ream.	Thickness per ream.	Weight of equal bulks, *e.g.*, 5 inches.	Number of sheets in 5 inches.
		lbs.	inches.	lbs.	
1.	Between couch- and press-rolls .	69·0	5·04	68·5	476
2.	Between press-rolls and cylinders	68·8	4·65	74·0	516
3.	Rough machine-finished . .	59·6	3·87	77·0	620
4.	No. 3 lightly glazed, not T.S. .	59·5	2·96	100·5	810
5.	Nc. 3 heavy glazed, not T.S. .	59·8	2·77	108·0	866
6.	Tub-sized, not glazed . .	63·3	3·61	87·5	664
7.	No. 3 lightly glazed, T.S. . .	63·0	3·34	94.3	719
8.	No. 3 heavy glazed, T.S. . .	62·6	3·02	103·6	794

Variations in Bulk.—The differences in the substance and thickness are certainly interesting. The fact of their existence is well known, though the actual publication of a specific example now appears probably for the first time; but care is necessary in deducing any hard and fast conclusions from these

experiments. They are the results of an investigation made on one paper, and any suggestions arising can properly be applied only to this case. If, however, the results and conclusions obtained are repeated in similar investigations, and the relations found with the various physical qualities are consistent, then it will be possible to draw some useful facts from the experimental evidence which might and should eventually guide the paper-maker. It is necessary to emphasise the necessity of only establishing a law on the evidence of repeated experiment, and not on single cases, in which the danger of a mere coincidence is obvious enough.

The effect of the natural shrinkage of the wet paper obtained from the couch- and press-rolls is very marked. Under the contraction due to natural evaporation of the moisture, the weight per ream of the first two samples reaches a high figure. In the rough machine-finished paper the forces of evaporation, tension, and the pressure of felts against the hot cylinders tend to give practically the minimum figure.

The changes in the thickness of the paper are also interesting.

From sample *one* to sample *five* the reduction is uniform, the thickness of the first being 5 inches and of the fifth 2·77 inches per ream. The percentage loss of bulk at each stage may be seen in Table XL.

TABLE XL.—*Showing Reduction in Thickness of Paper at Various Stages.*

Sample.	Thickness of ream.	Relative thickness. No. 1=100.	Percentage loss.
1	5·0	100	0
2	4·65	92	8
3	3·87	77	23
4	2·96	59	41
5	2·77	55	45

The effect of the plate-glazing process is almost entirely confined to the reduction of bulk, and consequent relative increase in weight. The paper after glazing shows but little increase in area, so that the result of pressure as far as the weight is concerned is of a simple character. The increase in area determined by a few isolated measurements did not exceed $1\frac{1}{2}$ per cent.

The greatest reduction in bulk occurs with the first pressure of the plate-glazing rolls. The subsequent rolling merely improves the surface. Other important points in reference to plate glazing will arise later.

Volume Composition.—The results expressed in the familiar term of actual weight and thickness become still more interesting when studied in relation to the volume composition. The exact influence of each stage in the manufacture of the finished sheet is thus recorded in a form which shows the effect upon each constituent of the paper, and this is well illustrated by the special case under consideration. The volume composition of the paper at each stage in manufacture is set out in Table XLI.

Apparent Specific Gravity and Breaking Length.—The investigation of the special paper was continued with the view of determining the changes in physical qualities other than that of volume composition merely.

Observations were recorded as to the strength of the paper and the alterations in strength brought about by the several operations in manufacture.

Breaking Length.—The term "breaking length" is seldom used in England, paper-makers contenting themselves with expressing the strength in terms of the weight required to break a strip of given width. In this case it is

TABLE XLI.

Paper.	Observations.				Gramme per c.c.				Volume Composition per cent.			
	Thickness 10 pieces = vol. in c.c.	Weight of 10,000 sq. mm. Grammes.	Per cent. Ash.	Per cent. Gelatine.	Total.	Fibre.	Ash.	Gelatine.	Fibre. %	Ash. %	Air. %	Gelatine. %
1. Between couch- and press-rolls	2·68	1·6592	15		·619	·526	·093		35·1	3·7	61·2	
2. Between press-rolls and cylinders . .	2·46	1·6776	15		·682	·579	·103		38·6	4·1	57·3	
3. After cylinder, rough machine finished . .	2·05	1·4530	15		·709	·603	·106		40·2	4·2	55·6	
4. Light glazed, not tub-sized	1·57	1·4485	15		·922	·784	·138		52·3	5·5	42·2	
5. Heavy glazed, not tub-sized	1·46	1·4596	15		·999	·850	·149		56 7	6·0	37·3	
6. Tub-sized, not glazed .	1·91	1·5424	15	5	·808	·646	·122	·040	43·0	4·9	49·1	3·0
7. Tub-sized, then light glazed	1·77	1·5357	15	5	·867	·694	·130	·043	46·3	5·2	45·4	3·1
8. Tub-sized, then heavy glazed	1·60	1·5655	15	5	·979	·783	·147	·049	52·2	5·9	38·3	3·6

NOTE.—The weight of one c.c. of paper expresses its "apparent specific gravity." Hence the first column under the heading "Gramme per c.c." gives the apparent specific gravities of the paper at each stage.

necessary to record the width as well as the breaking strain, but by calculating the length of paper which, if suspended, would break of its own weight, a figure is obtained which is independent of the width, more or less. For example:

A paper 20″ by 30″ weighs 72 lbs. per ream, and has an average strength of 60 lbs., tested on a strip 1 inch wide. The weight of the strip tested, if 5 inches long and 1 inch wide, should be $\frac{1}{50}$th oz., as follows:

$$20 \times 30 \times 480 \text{ sq. in.} = 72 \times 16 \text{ oz.}$$
$$288{,}000 \text{ sq. in.} = 1152 \text{ oz.}$$
$$5 \text{ sq. in.} = \tfrac{1}{50}\text{th oz.}$$

If the breaking strain of the paper is 60 lbs. for a one-inch strip, then a weight of 60 lbs. suspended to the strip 5 inches long, when hung vertically would break the paper. If instead of an actual weight, a length of paper 1 inch wide equal to 60 lbs. is substituted, then "breaking length" is determined.

Since $\frac{1}{50}$th ounce is weight of strip 5 inches long
60 lbs. ,, ,, $(250 \times 16 \times 60)$ inches, or 6666 yards.

The breaking length is therefore 6666 yards, irrespective more or less of the width.

Tests for strength.—The strength of the special papers taken for investigation was determined in the usual way by taking six strips in the *machine* and *cross* directions, the dimensions of each strip being 1 inch wide, and about 5 inches long, giving a piece exactly 4 inches between the clamps of the apparatus.

The observations made, and the calculations worked out, were as follows:

(1) Strength in the machine direction. Mean of six tests.
(2) Strength in the cross direction. Mean of six tests.
(3) Average strength of the paper.
(4) Weight of a strip one metre in length, and 25 mm. wide.
(5) Calculation of the "breaking length" of paper.
(6) Calculation of "breaking weight per unit of sectional area."

TABLE XLII.—*Details of Tests for Strength.*

	Mean
No. 1. Between couch-rolls and press-rolls:	
Machine direction, 16·0, 16·0, 17·5, 16·5, 16·0, 17·5	16·6
Cross direction, 16·0, 16·0, 14·0, 13·0, 13·0	14·4
Final mean	15·5
No. 2. Between press-rolls and cylinders:	
Machine direction, 20·0, 16·0, 18·0, 18·0, 16·0, 14·5	17·0
Cross direction, 15·0, 16·0, 13·5, 14·0, 14·0, 14·0, 11·5	14·0
Final mean	15·5
No. 3. Rough machine-finished	
Machine direction, 28·0, 28·5, 27·5, 26·5, 30·0, 30·0	28·4
Cross direction, 19·0, 18·0, 17·5, 18·0, 17·5	18·0
Final mean	23·2
No. 4. Lightly glazed, not tub-sized	
Machine direction, 30·0, 35·0, 33·0, 31·0, 32·0, 34·5	32·6
Cross direction, 20·0, 20·0, 18·0, 19·0, 21·0	19·6
Final mean	26·1

No. 5. Heavy glazed, not tub-sized:		
Machine direction, 30·0, 33·0, 30·5, 31·0, 31·5, 28·0	.	30·5
Cross direction, 18·0, 19·5, 18·0, 18·0, 19·0, 18·5	.	18·5
Final mean	.	24·5
No. 6. Tub-sized, but not glazed:		
Machine direction, 35·0, 36·0, 35·0, 34·5, 35·0	.	35·1
Cross direction, 19·0, 20·0, 21·5, 21·5, 19·0, 23·0	.	20·7
Final mean	.	27·9
No. 7. Lightly glazed after tub-sizing:		
Machine direction, 38·5, 39·5, 38·5, 38·0, 38·0, 38·5	.	38·5
Cross direction, 19·0, 18·0, 18·0, 19·5, 20·5, 20·5	.	19·3
Final mean	.	28·9
No. 8. Heavy glazed after tub-sizing:		
Machine direction, 36·5, 34·0, 35·5, 34·5, 36·0, 35·5	.	35·3
Cross direction, 18·5, 20·0, 20·5, 20·5, 20·0, 18·5	.	19·7
Final mean	.	27·5

The observations and calculations mentioned are summarised in Table XLIV.

The first items of interest in Table XLIV. are those referring to the strength.

Variations in strength.—The mean strength of the finished paper as usually put on the market, viz., that of the heavily glazed tub-sized paper, appears to be 27½ lbs. The *maximum* strength is apparently, however, obtained in the tub-sized paper which has not been so severely rolled in glazing, viz., 29 lbs.

Since the mean strength of the paper, after it leaves the couch-rolls, is only 15½ lbs., it is instructive to trace the several influences at work which add to the strength.

Apparently the press-rolls contribute nothing, and the first increase is due to the action of the felts and heat on the drying cylinders. This amounts to about 7 lbs.

The sample lightly glazed shows an additional 3 lbs., and the sample lightly glazed after tub-sizing another 3 lbs.

Hence:

Original strength	.	15½ lbs.
First addition on the drying cylinders	.	7½ ,,
Second addition due to sizing	.	3 ,,
Third addition due to glazing	.	3 ,,
Total	.	29 lbs.

It is further noticeable that nearly the whole of this increase is in the machine direction, as clearly shown in Table XLIII.

For an increase of 22 lbs. in the machine direction there is an increase of only 5 lbs. in the cross direction. It is curious that in the papers taken off the machine before reaching the drying cylinders, the strength of the machine direction is almost equalled by that of the cross direction. This was certainly an unexpected result and, should it be confirmed by independent observations on the part of other paper-makers, worthy of some investigation. Evidently the commonly accepted notions of the influence of shake on the relative strengths of the two directions may require modification. In these tests the figures tend to suggest that the influences at work during the later stages of manufacture are of greater importance. The great increase during the process of drying on the machine is most suggestive.

The "breaking length" is a simple function of the paper, and varies at each stage of manufacture as shown in the table.

TABLE XLIII.

No.	Paper.	Strength.			Increase (approximate).		
		m.	c.	Mean.	m.	c.	Mean.
1.	Couch- and press-rolls .	16·6	14·4	15·5			
3.	Rough machine-finished .	28·4	18·0	23·2	11·8	3·6	7·7
4.	Lightly glazed, not T.S. .	32·6	19·6	26·1	4·2	1·6	3·0
7.	Lightly glazed, T.S. . .	38·5	19·3	28·9	6·0	—	3·0
	Total .				22·0	5·2	13·7

Sectional Area Breaking Weight.—The "breaking weight per unit of sectional area" is determined by an equally simple calculation. The strip taken for testing was one inch (25·4 mm.), but the strength for a strip exactly 25 mm. does not alter materially. Its thickness is dependent on the particular stage of manufacture. For example, in paper No. 7, which is the finished sheet after tub-sizing and glazing:

Thickness of a single sheet . . .	0·177 mm.
Weight of sheet 1000 sq. mm. . .	0·15357 gm.
Breaking weight of strip	13,140 gms.

The area of a section of this strip will be width × thickness.

$$\begin{aligned}\text{Area} &= w \times t\\ &= 25 \times \cdot 177 \text{ sq. mm.}\\ &= 4{\cdot}425 \text{ sq. mm.}\end{aligned}$$

The breaking weight sustained by a strip having a sectional area of 4·425 sq. mm. is 13,140 grammes. Hence for *one sq. mm.* the breaking weight is 13140 divided by 4·425 or 2969 grammes.

The figures giving this function of the several papers have been calculated on this simple basis.

Effect of Glazing.—A careful study of these qualities of paper reveals several points of interest, which cannot fail to have a practical bearing on the manufacture of paper as soon as the subject has been more fully investigated by those who are in a position to make more complete experiments in the paper-mill.

Thus the relation of strength to the amount of glazing and to the bulk of the paper is evidently important. The calendering and plate glazing adds to the strength of a paper considerably. As the pressure increases so the strength increases, *up to a certain point*, after which it diminishes. If the pressure is too high the strength suffers accordingly. This is indicated in Table XLIII.

The amount of pressure applied to a paper is, however, regulated by the amount of surface and finish desired, and is not determined by considerations of strength and bulk to any great extent. In the majority of cases the surface demanded by the buyer of a certain paper requires an amount of plate glazing which reduces the strength to a point below the maximum.

The comparison of breaking length with breaking weight per unit of sectional area becomes interesting in this connection because the latter increases instead

of diminishing. The gradual decrease in breaking length is accompanied by a corresponding increase in the sectional area breaking weight.

In papers Nos. 7 and 8 there is a loss of 7 per cent. of strength in the breaking length due to excess of glazing over that which gives the maximum strength, but a gain of 7 per cent. in the sectional area breaking weight.

Note.—The term "heavy glazed" denotes the amount of normal glazing necessary for the paper before it can be considered finished. The term "light glazed" denotes that the paper had not been rolled to the desired extent.

According to Table XLI. the decrease in the "breaking length" coincides with a volume composition in which the percentage of *air space* is below 40 per cent.

The author finds this to be the case with many papers, and it is possible that the volume composition of papers carefully recorded as a matter of laboratory routine in the mill will throw a great deal of light upon this important question of maximum strength in relation to bulk. The figures relating to volume composition as set out in Table XLI. should be studied in their relation to the figures representing the strength.

Apparent Specific Gravity.—The next point of interest is the last column of Table XLIV. which shows that the breaking length of a paper multiplied by its apparent specific gravity gives exactly the breaking weight per unit of sectional area. It may seem curious that such apparently different qualities should be so closely connected. The mathematical reasons for this relation of the strength qualities are adequately set out and explained by the authors of the "C B.S. Units" in their pamphlet.

Stretch.—The behaviour of the paper when submitted to tension was also recorded. A note was made of the amount of stretch which each paper indicated when tested for strength. The *temporary* and *permanent* stretch was taken in most cases as follows:

Two lines were drawn exactly four inches apart on the strip of paper before it was put into the testing-machine. The total stretch was registered in the usual manner by the machine. The permanent stretch was observed by bringing the fractured pieces together again very carefully and measuring the exact distance between the two lines.

The *temporary* stretch was taken as being the difference between the total and permanent.

The elasticity of the paper is given in Table XLV. Of course, a piece of paper when pulled takes on a permanent *set* at once, and this can be shown by putting a strip in the paper-testing machine and stretching it to within a small percentage of its total breaking weight, and releasing it before fracture.

The total stretch is highest with the papers of greatest bulk. The proportion of the total stretch which appears to be permanent in its nature, as far as the normal finished paper is concerned, averages 40–45 per cent.

The practical interpretation of the figures which represent the stretch of a paper, and their precise value in determining the wearing quality of a high-class paper has yet to be accurately determined. In the case of a bank-note or ledger paper, for example, we may ascertain fairly well the wearing quality by a folding test made under suitable conditions, noting the number of small pinholes worn into the paper by each successive five, ten or twenty foldings, as the case may be. The results obtained should be properly tabulated, and the behaviour of the paper subsequently in commercial use followed up. Unfortunately this is too often impossible or exceedingly difficult, but it is certainly a matter which the paper-maker and stationer might work out mutually to their common advantage.

TABLE XLIV.

Paper.	Weight per Metre Length of Strip, 25 mm. wide. Grammes.	Strength (lbs.).			Mean Strength of Paper in Grammes.	Breaking Length in Metres.	Breaking Weight per unit of Sectional Area.	Breaking Length multiplied by Specific Gravity.
		Machine.	Cross.	Mean.				
1. Between couch- and press-rolls .	4·148	16·6	14·4	15·5	7,045	1698	1052	1052
2. Between press-rolls and cylinders	4·194	17·0	14·0	15·5	7,045	1680	1145	1145
3. Rough machine-finished . .	3·6325	28·4	18·0	23·2	10,545	2903	2057	2058
4. Lightly glazed, not tub-sized .	3·6212	32·6	19·6	26·1	11,864	3277	3023	3024
5. Heavy glazed, not tub-sized .	3·649	30·5	18·5	24·5	11,136	3052	3051	3050
6. Tub-sized, but not glazed . .	3·856	35·1	20·7	27·9	12,681	3288	2655	2656
7. Lightly glazed, after tub-sizing .	3·8392	38·5	19·3	28·9	13,140	3422	2969	2967
8. Heavily glazed, after tub-sizing .	3·9137	35·3	19·7	27·5	12,500	3191	3125	3124

TABLE XLV.

No.	Description.	Permanent Stretch. Per cent.	Temporary Stretch. Per cent.	Total Stretch. Per cent.	Proportion of Permanent Stretch in the Total. Per cent.
1.	Between couch-rolls and press-rolls. . . .	—	—	7·8	—
2.	Between press-rolls and drying cylinders . .	3·9	2·5	6·4	60·9
3.	After drying cylinders machine-finished . . .	2·0	2·4	4·4	45·5
4.	Lightly glazed, before tubsizing	1·7	2·3	4·0	42·5
5.	Heavy glazed, before tubsizing	1·8	2·1	3·9	46·0
6.	Paper tubsized, but not glazed . . .	—	—	5·5	—
7.	Lightly glazed, after tubsizing	2·0	2·8	4·8	41·5
8.	Heavy glazed, after tubsizing	2·2	2·8	5·0	44·0

ADDENDUM.

Although the measurements of the physical qualities of paper necessary for the determination of volume composition are comparatively simple, yet the calculations may seem somewhat complicated.

The fact that the measurements are recorded in terms of millimetres, grammes, and cubic centimetres may prove embarrassing to some readers, but the metrical system offers a ready means for convenient observation, and reduces the amount of calculation to a minimum far more readily than the system of English weights and measures, which is cumbersome because there is no simple relation between the units of length, weight and volume.

In the metrical system the units are much simpler.

Unit of weight . . . . . . 1 gramme.
Unit of length . . . . . . 1 centimetre.
Unit of solid capacity . . . . 1 cubic centimetre.

One gramme of water = one cubic centimetre.

The equivalent values of the English and metrical units are as follows :

1 gramme (gm.) = ·0353 ounce.
1 centimetre (cm.) = ·3937 inch.
1 millimetre (mm.) = $\frac{1}{10}$th of a cm. = ·039 inch.
1 cubic centimetre (c.c.) = ·061 cubic inch.

An explanation of the idea of volume composition can be given to those who are more familiar with the English units of pounds and inches, by the statement of a case, and calculation of composition by volume by ordinary processes, avoiding all decimals and other unusual fractions.

Example.—A paper having the substance 72 lbs. double crown contains 15 per cent. ash, with a negligible percentage of rosin size. Its thickness measured in thousandths of an inch is $10\frac{1}{2}$.

A sheet of this paper cut to a size of 40 inches by 25, having a thickness in thousandths of an inch of $10\frac{1}{2}$, and a weight of exactly $\frac{1}{4}$ lb., has a volume of $10\frac{1}{2}$ cubic inches.

$$\text{Volume} = \text{length} \times \text{width} \times \text{thickness}$$
$$= 40 \times 25 \times \frac{10\frac{1}{2}}{1000} = 10\tfrac{1}{2}$$

In other words the actual calculation of volume is avoided by taking a sheet 40 inches by 25, because with this size the reading on the thickness gauge gives the volume at once. It is not always possible to take a sheet this size, but an area of 1000 square inches is needed. For this ten pieces each 10 inches by 10 would do, or twenty-five sheets 8 inches by 5, or as an alternative the weight of a single sheet cut 10″ by 10″, multiplied by 10.

At this stage of the calculations the observations are:

Table XLVI.

Thickness in thousandths of an inch, *i.e.*, Volume in cubic inches.	Weight of 1000 square inches.	Per cent. of Ash.
$10\frac{1}{2}$	$\frac{1}{4}$ lb.	15

In order to work out the volume composition without employing unusual fractions the weight per cubic foot is required.

1728 cubic inches = 1 cubic foot.

Since $10\frac{1}{2}$ cubic inches weigh $\frac{1}{4}$ lb.

$1 \text{ cubic foot} = \frac{1}{4} \div 10\frac{1}{2} \times 1728 = 41 \text{ lbs.}$

From which follows:

Table XLVII.

Volume in cubic feet.	Weight of one cubic foot of Paper.	Weight of Ash in one cubic foot of Paper.
1	41 lbs.	6 lbs.

The weight of ash in one cubic foot is 15 per cent. of 41 lbs. = 6 lbs. approximately.

Again to avoid fractions, the weight of 16 cubic feet must be calculated, an arbitrary figure selected because 16 cubic feet solid measure occupies the same volume as 100 gallons liquid measure and the observations will be needed in the later stages of calculation.

It will be convenient in this case to write out the result as expressing the weight of paper, &c., in 100 gallons of paper, a somewhat peculiar and eccentric expression, the reason for which will be apparent later on.

Multiplying the above figures by 16 the result is:

Table XLVIII.—*Lbs. per* 16 *cubic feet of paper* (*or per* 100 *gallons*).

Total weight.	Ash.	Fibre.
656 lbs.	96 lbs.	560 lbs.

The next problem is to determine what proportion of the total volume, *i.e.*, of 100 gallons, is occupied by the fibre and how much by the ash.

To do this, reference must be made to the subject of specific gravity. The specific gravity of ordinary loadings used in paper, such as china-clay, is $2\frac{1}{2}$. That is, one gallon of china-clay (solid) will weigh $2\frac{1}{2}$ times the weight of an equal volume of water.

10 lbs. is the weight of				one gallon of water.
25	,,	,,	,,	equivalent volume of ash.
96	,,	,,	,,	4 gallons of ash (approx.).

Similarly the specific gravity of fibre substance, or cellulose, is $1\frac{1}{2}$, so that one gallon of solid fibre has $1\frac{1}{2}$ times the weight of a gallon of water.

10 lbs. is the weight of one gallon of water.
15 lbs. is the weight of one gallon of fibre.
560 lbs. is the weight of 37 gallons of fibre.

Now the total volume of the paper is 100. Of this, 37 is fibre and 4 ash, and the balance, 59, must obviously be air space.

The *volume composition* of this paper is therefore:

Fibre	37	per cent.	by volume.
Ash	4	,,	,,
Air space	59	,,	,,
	100		

The figure representing the total weight of 100 gallons paper is in reality the "apparent specific gravity" of the paper.

This follows from the simple fact:

100 volumes (*i.e*, gallons) of water weigh 1000 lbs.
100 volumes of paper weigh 656 lbs.

If the specific gravity of water is 1000, then the sp. gr. of the paper is 656. It is usual to take the sp. gr. of water as 1, and in that case the sp. gr. of the paper would be a decimal fraction 0·656.

This is the chief reason for finally calculating the weight per 100 gallons of paper, but the process involves an unusual and roundabout method of calculation.

Metrical System.

With the metrical system the process of calculation is a simple matter, and the measurements can be accurately made on small pieces of paper.

The observations in the case of the paper already mentioned are as follows:

Table XLIX.

Thickness of 10 discs in mm. or Volume in c.c.	Weight of 10,000 square mm. Grammes.	Ash per cent.
2·66	1·75	15·0

The determination of the weight of fibre and ash in some unit of volume, in this case a centimetre, is very simple.

2·66 c.c. of paper weighs 1·75 grammes of which 15 per cent. (equal to 0·2625 grammes) is ash, and 1·4875 grammes is fibre.

The respective weights per 1 c.c. are as follows:

TABLE L.—*Grammes per 1 c.c.*

Total Paper.	Fibre.	Ash.
·657	·560	0·97

Pursuing the same reasoning as above, the next step is to calculate the exact volume of space occupied by ·560 gramme of fibre and ·097 gramme of ash respectively.

The question of specific gravity comes in again with the metrical system. On account of the simple units the specific gravity of any substance is quickly found.

In the ordinary way the sp. gr. is (weight of a certain volume of substance) divided by (weight of an equal volume of water).

Since the figure which represents the weight of a certain volume of water represents the volume itself (*i.e.*, 15 grammes is the weight of 15 c.c.), it follows that

Specific gravity equals weight divided by volume.
Therefore volume equals weight divided by specific gravity.

From this it is clear that the volume occupied by ·560 gramme of fibre = (·560 ÷ 1·5) c.c. and the volume occupied by ·097 gramme of ash = (·097 ÷ 2·5) c.c. in the actual 1 c.c. of paper.

This will give in 100 c.c. of paper:

Fibre	100 (·560 ÷ 1·5) = 37 c.c.
Ash	100 (·097 ÷ 2·5) = 4 ,,
	Air space = Balance = 59 ,,
	100 c.c.

TABLE LI.—*Summary and Observations under the Metric System.*

Observations.			Grammes per c.c.			Volume Composition per cent.		
Thickness of 10 pieces = volume in c.c.	Weight of 10,000 square mm.	Per cent. Ash.	Total Paper. Grammes.	Fibre. Grammes.	Ash. Grammes.	Fibre. per cent.	Ash. per cent.	Air. per cent.
2·66	1·75	15	·657	·560	·097	37	4	59

CHAPTER XV

CELLULOSE AND ITS DERIVATIVES*

Celluloses, simple and compound—Cellulose and water—Solvents—Action of dilute alkalies and acids—Action of strong alkalies and acids—Industrial uses of cellulose derivatives —Investigation and analysis of raw fibres—Percentage composition of certain well-known plants.

Celluloses.—The white fibrous substance obtained by the suitable chemical treatment of cotton, linen, hemp, esparto, wood and many other plants is known as *cellulose.*

The fibre obtained from *cotton* is practically a pure homogeneous substance having the composition $C_6H_{10}O_5$, as follows :

C.	Carbon	44·2
H.	Hydrogen	6·3
O.	Oxygen	49·5

The classification of the many fibre-yielding plants known to paper-makers, based upon the chemical constitution of the plant, may be briefly summarised by reference to certain broad distinguishing characteristics. The *simple cellulose* is represented by the *cotton* fibre, which is a pure cellulose mixed with a small proportion of fatty and colouring matters readily removed by simple solvents. All other well-known paper-making fibres belong to the class of *compound celluloses,* in which the pure cellulose is intimately associated with other organic compounds of complex constitution.

Cellulose.

The only fibre used by paper-makers which is a simple cellulose is *cotton.* Its composition is :

	(Church.)
Cellulose	91·15
Fat	0·51
Aqueous extract	0·67
Ash	0·11
Water	7·56
	100·00

Compound Celluloses.

The many fibres known as compound celluloses can be classified as follows:

(A) *Pecto-celluloses*, containing a high percentage of fibre, such as:

* For a complete account of cellulose the following books should be consulted : "Papermaking," Cross and Bevan ; "Cellulose," Cross and Bevan.

	Per cent. of Cellulose.
Flax	82·0
Hemp	77·0
Ramie	76·0
Sunn hemp	80·0
Manila	64·0

(B) *Pecto-celluloses*, containing a low percentage of fibre, such as :

	Per cent. of Cellulose.
Bamboo	50·0
Sugar-cane	50·0
Straw	46·0
Esparto	48·0
Adansonia	49·0

(C) *Ligno-celluloses*, containing lignified fibre, such as :

	Per cent. of Cellulose.
New Zealand Flax	86·0
Jute	64·0
Wood (pine)	57·0
Wood (poplar)	53·0

(D) *Adipo-celluloses*, containing a very low percentage of cellulose. Of no value for paper-making.

Cork.
Cuticular tissues of plant stems, &c.

This classification is only approximately correct. Thus, *wood* is a mixture of ligno-cellulose and pecto-cellulose, but the proportion of the latter is small, and it is therefore convenient to classify the plant as a ligno-cellulose. In the same way *esparto* is a mixture of pecto-cellulose, ligno-cellulose, and adipo-cellulose, but since the first named is the predominant constituent, it is best classed as a pecto-cellulose.

The Derivatives of Cellulose.—Although cellulose is a substance remarkably inert towards chemical reagents applied under ordinary conditions, a character which renders it extremely useful for many commercial purposes, yet it can be converted into a large number of compounds of the greatest industrial value.

Cellulose and Water. *Air-dry cellulose.*—The cellulose represented by the empirical formula $C_6H_{10}O_5$ has the power of absorbing a certain proportion of moisture from the air, the amount being greatest in damp weather. *Air-dry* cellulose as distinct from *bone-dry* cellulose will contain 8 to 12 per cent. of atmospheric moisture.

Imitation parchment.—The natural cellulose isolated from vegetable plants is an opaque body. When beaten for a prolonged period in the ordinary "Hollander" beating-engine, it undergoes a remarkable change, losing its fibrous structure and giving a curious transparent cellulose, owing to the assimilation of water. In this form it is used as *imitation parchment.*

Cellulith.—If the beating of the pulp be continued for thirty to forty-eight hours the cellulose becomes very slimy and transparent, capable of hardening under pressure to a mass of horn-like appearance, which can actually be turned in a lathe. The substance so obtained has received the commercial name of *cellulith.*

Cellulose and Solvents.—Cellulose is soluble in certain solutions containing zinc, copper, or similar metallic salts.

Zinc chloride. Vulcanised fibre.—Ten parts of cellulose stirred into a solution of fifty parts zinc chloride in eighty parts of water, carefully heated at 80° C., and subsequently evaporated on a water bath give a clear syrupy solution of cellulose. Several important commercial applications of this reaction are known. When the syrup is forced under high pressure through small tubes into alcohol, it yields a thread which hardens on expose to air. This thread when carbonised gives the carbon filament used for *incandescent electric lamps*. The manufacture of vulcanised sheets also depends upon this property of cellulose.

Copper oxide and ammonia. Willesden goods.—A mixture prepared by forcing air through a solution of copper oxide in ammonia dissolves cellulose readily. The strong solution is somewhat gelatinous, and when treated with acid the cellulose is reprecipitated as a white jelly-like mass, which hardens on drying.

Advantage is taken of this behaviour of cellulose in the manufacture of *Willesden goods*, such as roofing, and other fabrics which are thus rendered waterproof.

Cellulose and Weak Alkaline Solutions. *Textile treatment.*—Weak solutions of caustic soda, containing 2–3 per cent. of caustic have very little action upon cellulose even at 212° Fahrenheit.

The inertness of cellulose in this respect is of the greatest value in the *textile trades*, since a slight alkaline treatment removes fatty matter from the fibres or from textiles without affecting the goods.

Paper.—Solutions containing 4 to 10 per cent. of caustic soda when used for digesting vegetable fibres at high temperatures, brought about by heating in closed vessels under pressure, dissolve out non-cellulose constituents from the complex plant substance and set free the cellulose in a fibrous condition ready for *paper-making*.

Cellulose and Strong Alkaline Solutions. *Mercerised cotton.*—Strong caustic soda acts upon cellulose to produce an effect known as "Mercerisation," a term applied to a process for treating cotton, after the name of the inventor, Mercer. When cotton is immersed in strong caustic soda in the cold, it shrinks and becomes silky in appearance. The chemical changes are very remarkable, the soda entering into combination with the cellulose in the early stages of mercerisation, and being liberated in the later stages. Textile cotton goods are now treated on a large scale for the production of the well-known silky, lustrous *mercerised fabrics*.

Oxalic acid.—Cellulose heated with concentrated solutions of soda or potash and evaporated to dryness is converted into oxalic acid. On a practical scale sawdust is largely utilised for the manufacture of *oxalic acid*.

Cellulose and Weak Acids. *Dyeing.*—Acetic acid has very slight action upon cellulose either in the cold or at a high temperature. This fact is utilised commercially when textile goods are dyed and made up into *coloured fabrics*.

Bleaching.—Mineral acids, such as hydrochloric and sulphuric, when used cold and in dilute solution, do not act rapidly upon cellulose. On account of this the operations of bleaching and dyeing can be effected readily. Additions of dilute acids to vats containing textile goods or paper pulp in a solution of chloride of lime aids the process of *bleaching*.

Separating cotton from wool.—Mineral acids in dilute solution act upon cellulose when heated, destroying the fibre and rendering it soft. The cellulose can then be broken and rubbed into a powder. Acids do not act upon wool in this way. Advantage is taken of this difference in behaviour to remove burrs

from wool and cotton from woollen goods when the latter are mixtures of cotton and wool, and so bring about a *separation of vegetable from animal fibres.*

Disintegration of Cellulose.—Mineral acids in dilute solution allowed to remain in contact with cellulose tissues under ordinary atmospheric conditions bring about a gradual disintegration of the fibre into a powdery non-fibrous condition, the substance produced being termed *hydro-cellulose*. Hence paper in which any traces of free acid are present slowly breaks up entirely.

Cellulose and Strong Sulphuric Acid. *Glucose and alcohol.*—Concentrated sulphuric acid of specific gravity 1·60 to 1·70 dissolves dry cellulose, forming a pale yellow solution which, on addition of water and prolonged boiling, yields *glucose*. On fermentation the glucose can be converted into alcohol.

On a commercial scale it is possible to convert certain forms of cellulose, and allied substances, such as starch, into *glucose* and *alcohol*.

Parchment paper.—Cellulose in the form of rag or wood paper passed through a bath of sulphuric acid of suitable strength is converted into *parchment paper*.

Cellulose and Nitric Acid.—A large number of commercial products are obtained by the action of nitric acid upon cellulose.

Gun-cotton.—Cotton immersed for twenty-four hours at a low temperature of 8 to 10° C. in a solution of three parts of nitric acid (sp. gr. 1·5) and one part of sulphuric acid (sp. gr. 1·84) is converted into cellulose hexa-nitrate, commercially known as the most highly explosive *gun-cotton*.

The hexa-nitrate, when heated with nitric acid to 80° C., dissolves, and can be reprecipitated as a cellulose nitrate containing less nitric acid, viz., cellulose penta-nitrate, which is a less explosive *gun-cotton*.

Collodion.—Cellulose nitrates of less complexity are formed when cellulose is heated for short periods of twenty to thirty minutes at higher temperatures with more dilute acid. These nitrates are soluble in ether-alcohol, and are of commercial value for photography as *collodion pyroxyline*, for surgical purposes in dressing wounds, and for making tips of matches waterproof.

Xylonite.—The nitrates of cellulose, treated with alcohol-ether, acetone and other suitable solvents, and then mixed with camphor and suitable vegetable oils, yield such commercial products as *xylonite*, *celluloid*, &c.

Artificial silk.—Nitrated cellulose, when dissolved in alcohol-ether to a syrupy solution, and forced under great pressure through small glass tubes into water, yields a solid smooth thread which can be wound up like silk on a bobbin. By subsequent treatment with ammonium sulphide, the combined nitric acid is removed, and the thread obtained possesses a fine lustre, being capable of taking any suitable dye. This is known as lustra-cellulose, or artificial silk.

Cellulose and Acetic Acid.—Cellulose is unacted upon by acetic acid even in a boiling solution, but it is converted into cellulose acetate by the use of acetic anhydride, and forms a thick viscous solution.

The acetates of cellulose can be used to replace the nitrates for many purposes, being non-explosive.

Cellulose and Carbon Bisulphide. *Viscoid.*—Cellulose itself is not acted upon by carbon bisulphide, but when converted into *alkali-cellulose*, it may be worked up into some remarkable products.

Cellulose is treated with a solution containing 15 per cent. of caustic soda, squeezed until it holds about three times its weight of liquid. It is then shaken up in a closed vessel with about 50 per cent. of its weight of carbon bisulphide, and after three hours covered with water. A golden yellow solution is obtained. If this solution is allowed to stand it sets to a jelly, forming a hard mass of hydrated cellulose which gradually shrinks, the chemical by-products going into solution. The horny mass can be produced more quickly by heat.

The substance so obtained can be turned in a lathe for the manufacture of goods resembling ebony and xylonite. It is called *viscoid.*

Viscose.—If the viscous solution is diluted with water, it can be used for sizing certain grades of paper, by the simple method of mixing it with the pulp in the beating-engine and decomposing with sulphate of magnesia.

Smokeless gunpowder.—The structureless, regenerated cellulose obtained by suitable treatment of viscose, when nitrated yields smokeless powder.

Cellulose nitrates produced in this way, as well as cellulose nitrates prepared from cellulose direct, are the principal ingredients of such explosives as *cordite, ballistite, maximite,* &c.

Cellulose and Ferments. *Sugars.*—The complex celluloses which are found as constituents of many seeds, and in cereals, possessing qualities quite distinct from the fibrous celluloses of ordinary plant life, yield to the action of ferments, producing, for the most part, *crystallisable sugars*, and allied substances.

Ordinary fibrous cellulose is not susceptible to the action of ferments.

Cellulose and Heat. *Charcoal, acetic acid.*—When certain complex celluloses, such as peat and wood, are submitted to dry distillation, valuable products are obtained, such as *charcoal, wood spirit,* and *crude acetic acid.* The utilisation of waste sawdust, wood shavings, &c., for the manufacture of these substances is now an important industry.

It is evident from this *resumé* of the derivatives of cellulose that many plants which may not be suitable for textile purposes or for paper-making would have some value for other industries. The chemical examination of raw fibres therefore becomes an essential and integral part of an investigation as to the utility of any plant.

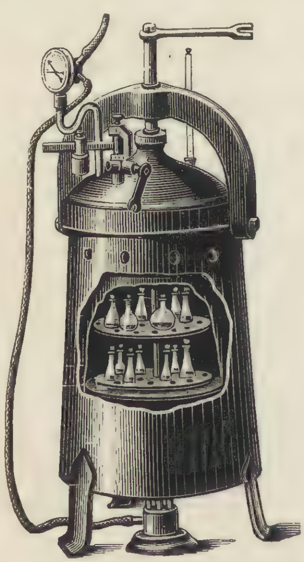


Fig. 152.—Digester used in Experimental Investigations of Fibres.

The examination of raw fibres is usually carried out with one of two objects in view:

(1) The determination of suitability for paper-making, the yield of cellulose, and approximate cost of treatment.

(2) The more complete investigation into the chemical and physical properties of the fibre, as a measure of its probable value for industrial purposes, and not necessarily for paper-making alone.

Simple Analysis for Papermaking Fibre.—The examination of the raw fibre in its simplest form involves digestion of a known weight of the air-dry substance in a closed vessel under pressure for a known period, the fibre being carefully washed, dried and weighed after treatment. The experimental autoclave usually consists of an upright copper cylindrical vessel, fitted with a removable lid, a safety-valve, steam-gauge, and oil cup for a thermometer. A convenient weight of fibre, cut into small lengths, is placed in the autoclave, covered with a measured volume of the chemical reagent made up to an exact strength, as experience may suggest, and heated gradually to a given pressure, which is then maintained for several hours.

The fibre may be treated in a copper or iron vessel with caustic soda (soda treatment) or by means of a solution containing bisulphite of lime and free sulphurous acid in a *lead-lined* copper or iron vessel (bisulphite treatment).

It is impossible to lay down a rigid scheme of treatment, as the condition of the raw fibre determines very largely the methods necessary for isolation of the cellulose.

In digesting a fibre with caustic soda, a preliminary trial will serve to show the conditions likely to give the maximum yield of cellulose with a minimum expenditure of time and chemicals. Thus 200 grammes of fibre boiled with 25 per cent. of its weight of caustic soda made up to a solution of 1·050 specific gravity, for four hours at 60 lb. pressure may be taken as a trial boil. The amount of soda *not consumed* by the fibre is then determined, and a second trial conducted with caustic soda just in excess of that consumed previously. Any necessary alteration in pressure and time of boiling can be determined by the general appearance of the boiled fibre.

The amount of caustic soda required for experimental as well as practical purposes is not altogether determined by measuring the active soda remaining in solution. There must be sufficient liquor to cover the fibre; this liquor must be of sufficient strength (*i.e.*, specific gravity); so that light bulky fibres may require comparatively larger volumes of liquor.

Example. Soda process.

TABLE LII.

	Trial 1.	Trial 2.	Trial 3.
Weight of raw fibre (grammes)	200	200	200
Caustic soda added	50	26	26
Time of boiling (hours)	8	8	6
Pressure (lbs. per square inch)	60	60	60
Weight of air-dry fibre	88	92	90
Condition of fibre	over boiled	well boiled	sufficiently boiled
Per cent. of caustic soda added	25	13	13
Per cent. of air-dry fibre	44	46	45
Per cent. of bleach consumed	8	9	9

The air-dried fibre is then bleached under suitable conditions, the amount of bleach being carefully measured, and the actual consumption determined. The conditions of treatment are by no means so rigid as the above table would appear to indicate, since the material can be boiled to give a hard strong fibre or a soft tender fibre as required, but the figures serve to illustrate the nature of the investigation.

Example. Sulphite process.

TABLE LIII.

	Trial 1.	Trial 2.	Trial 3.
Weight of raw fibre (grammes)	200	200	200
Volume of bisulphite liquor (cubic centimetres)	1000	1000	1000
Specific gravity	1·060	1·040	1·040
Time of boiling (hours)	10	10	8
Pressure (lbs. per square inch)	60	60	60
Excess of free sulphurous acid	nil	nil	traces
Condition of pulp	very soft	soft	slightly hard
Per cent. of air-dry pulp obtained	36	38	40

The sulphite process requires digestion of the raw material with a solution of bisulphite of lime and free sulphurous acid in a lead-lined vessel. Small portions of liquor can be drawn off from the autoclave during the boiling operation and tested, so that the changes going on can be readily watched. In other respects the analysis closely resembles that made use of in the soda treatment.

Complete Analysis of a Fibre.—Under the scheme of investigation recommended by Cross and Bevan the analysis of a fibre should include the following details:

Moisture.—Determined by drying a weighed quantity of the fibre at 110° C., the loss in weight being calculated as moisture.

Mineral constituents.—Determined by burning a weighed quantity of fibre to a white ash. The weight of ash obtained is a measure of the mineral constituents.

Hydrolysis.—The action of caustic soda on fibre, resolving it into insoluble and soluble constituents, which is known as hydrolysis.

(*a*) Loss due to boiling fibre for five minutes in a solution of caustic soda containing 1 per. cent. Na_2O.

(*b*) Loss due to boiling fibre under the same conditions for one hour instead of five minutes.

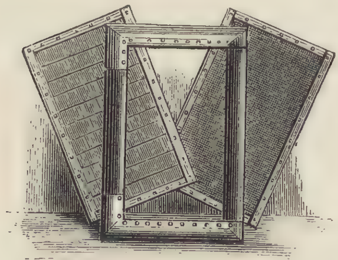
Cellulose.—A weighed quantity of fibre is boiled for thirty minutes with dilute alkali containing 1 per cent. Na_2O; thoroughly washed, squeezed out and exposed to the action of chlorine gas for one hour. It is then washed, thrown into a 2-per-cent. solution of sodium sulphite, which is gradually raised to the boiling-point. A small quantity of caustic soda is added (0·2 per cent. on the amount of solution) and the mixture boiled ten minutes.

The fibre is filtered off, washed with hot water, and bleached by immersion in a dilute solution of hypochlorite of soda (0·1 per cent. hypochlorite of soda). It is finally washed with water containing a little sulphurous acid, then with distilled water; squeezed, dried, and weighed.

This method gives a maximum yield of cellulose.

Mercerisation.—The fibre is soaked in a concentrated solution of caustic soda (30 per cent. of Na_2O) for one hour. It is then washed, dried and weighed. The loss of weight is carefully determined, and the action of the alkali on the fibre examined under the microscope.

Nitration.—A weighed quantity of fibre dried at 100° C. is placed in a mixture of equal volumes of nitric acid (1·5 sp. gr.) and sulphuric acid (1·83 sp gr.) for one hour at the ordinary temperature. The increase in weight is noted, and the colour of the resulting product.



Fig, 153.—Hand Moulds used in Experimental Investigations of Fibres.

Carbon percentage.—A weighed quantity of the fibre is treated with chromic anhydride and sulphuric acid in a flask, and the products of the combustion which takes place carried over into a special gas apparatus for the measurement of the carbon monoxide and carbon dioxide produced. This analysis determines the exact percentage of carbon in the fibre.

Acid purification.—A weighed quantity of fibre is digested in boiling acetic acid solution (containing 20 per cent. acetic acid), washed with alcohol, then with distilled water, dried and weighed. The loss in weight is taken as a measure of impurities, and the fibre thus purified is used for determination of carbon percentage.

TABLE LIV.—*Percentage Composition of Fibre-yielding Plants (authorities various).*

Constituent.	Cotton.	Flax.	Italian hemp.	Ramie.	Sunn hemp.	Manila hemp.	Bamboo.	Straw (wheat).	Esparto (Spanish).	Jute.	Beech.	Pine.	Poplar.
Cellulose . . .	91·15	82·00	77·13	75·83	80·00	64·07	50·13	46·60	48·25	63·76	45·23	57·00	62·77
Water . . .	7·56	8·60	8·80	8·74	9·60	11·73	8·56	9·85	9·38	9·86	12·50	13·77	12·10
Aqueous extract .	0·67	3·61	3·45	6·29	2·82	0·96	10·56	8·07	10·19	1·00	2·40	1·16	2·88
Pectous matter . .		2·72	9·25	6·07	6·41	21·60	24·84		26·39				
Lignin . . .								28·49		24·32	38·97	26·70	20·58
Fatty matter . .	0·51	2·37	0·55	0·20	0·55	0·62	0·78	1·49	2·07	0·38			
Ash	0·11	0·70	0·82	2·87	0·61	1·02	5·13	5·50	3·72	0·68	0·50	0·40	0·35
Resin											0·40	0·97	1·32
Yield of dry cellulose obtained in actual practice from good raw material . .	83	76					40	42	45	50		50	52

Furfural.—A weighed quantity of fibre is boiled with hydrochloric acid of 1·1 specific gravity under special conditions, and distilled. The distillate contains the substance called *furfural*, derived from the fibre. The weight of furfural-yielding constituents in the fibre can be determined by analytical methods.

Methoxyl.—This important constituent of ligno-celluloses is determined by analytical processes which involve :—boiling a weighed quantity of fibre with hydriodic acid, passing the methyl iodide formed into an alcoholic solution of silver nitrate, and calculating the amount of methoxyl from the silver iodide obtained.

Elementary analysis.—The percentages of carbon, hydrogen and oxygen are determined by well-known analytical methods.

CHAPTER XVI

HISTORY, CHRONOLOGY, AND STATISTICS

A Brief Historical Account of Paper.—The gradual evolution of paper as the medium for recording knowledge is interestingly set out in a book published by Matthias Koops in 1801, entitled "Historical Account of the Substances which have been used to describe Events, and to convey Ideas, from the Earliest Date to the Invention of Paper." Additional interest attaches to this work, since it was printed on paper manufactured from straw even at that early date.

The commemoration of important events was in ancient times effected by the planting of trees, the erection of heaps of stones, the recital of old traditions, and the memorising by succeeding generations of the stories of past heroes.

The art of writing having been discovered, more rapid advances were made in keeping accurate records on stones, metal and wood, frequent references to such being found in the Scriptures. Lead, soft clay, stone, wood were all pressed into service and gradually superseded in the times of the Romans by wax-covered boards, or *Pugillares cerei.*

The employment of thinner, more pliable material in the shape of palm leaves was early resorted to by the Egyptians, and Koops gives a detailed account of a number of interesting documents printed on leaves of this description.

From the leaves of trees, the attention of men was directed to the possibility of using the bark, and the interior bark (*liber*) was found suitable for the purpose. This Latin word *liber* came to signify a book, and to the collection of a number of such pieces of bark was given the name *volumen.*

The next stage in the evolution appears to have been the use of sheep- and goat-skins, the skins of fish and serpents, bones, intestines, and every conceivable material of a similar kind.

The first great step towards the present stage of perfection was the discovery of the possibilities of the Egyptian *Papyrus*, a tall, smooth-stemmed reed of triangular form, growing to a height of ten to fifteen feet, and terminating in a tuft of leaves. The soft pithy matter inside the stem was used for food, and the fibrous portion largely for cords, mats and wearing apparel, but the fame of the *papyrus* rests upon its application to the service of man as implied in the name of the plant which we have modified to the word *paper.*

The exact date of the use of the *papyrus* is unknown. It was in extensive use about B.C. 350, and probably much earlier. The fact that in the book of Isaiah (Isa. xix. 7) mention is made of "the paper-reeds by the brooks" is regarded by some writers as proof of the use of papyrus in the time of Isaiah, but the revised version of the Bible conveys no such impression.

The manufacture of papyrus leaves was brought to great perfection by the Romans, who removed the several fibrous layers from the stem of the plant by means of a pin, and spread them on a table, washing them with water. Two layers were placed across one another at right angles, gently beaten and pressed together, dried and polished. The dried sheets were sized with a cream

made from flour, and when finished measured about fifteen to sixteen inches in width, the length varying according to the number of sheets fastened together.

The extensive use to which papyrus was put may be judged from the fact that at the unearthing of the ruins of Herculaneum in 1753 no less than 1800 rolls were discovered, while recent explorations have resulted in enormous finds of documents written on papyri.

Parchment (from Latin, *pergamena*) was invented by the King of Pergamus, the necessity for a writing material arising from the exportation of papyrus having been prohibited by the King of Egypt.

The discovery of the art of making paper is usually conceded to the Chinese. The earliest date which can be fixed in connection with the subject is 704 A.D., the year when the Arabians acquired the knowledge at the capture of the City of Samarkand from the Chinese, and utilised raw cotton and cotton wool as the staple material.

Rapid advances were made in the art after its introduction into Europe by the Moors about the year 1000 A.D., the towns of Toledo and Valencia taking a prominent part in the manufacture.

The exact date when paper made of cotton was brought to England has not been determined. The earliest MSS. appears to date about 1049, printed on paper made probably in France. The industry seems to have flourished in France, Italy and Germany long before it was taken up in England.

The earliest trace of paper-making in England is to be found in a book, "De Proprietatibus Rerum" (About the properties of things), printed by Caxton, in which appears the following:

> "And John Tate, the younger, joye mote be brok
> Which late hathe in England, doo make this paper thynne,
> That now in our Englysh, this book is printed inne."

Tate's mill was near Stevenage in Hertfordshire, and an entry made in Henry VII.'s household book, dated May 25, 1498, reads: "For a rewarde geven to the paper mylne, 16*s*. 8*d*."

Spielman, of Dartford, erected a mill in 1588, employing about 600 work-people.

For a long period after this the manufacture of paper in England remained an undeveloped art, the paper being imported mainly from France as required, but in 1760 the celebrated "Whatman" mill was erected at Maidstone.

The improvements in the manufacture of paper between the years 1750 A.D. to 1800 A.D. were almost entirely the outcome of activity amongst paper-makers in France and Holland. The methods used for converting the rags into paper were slow and costly, as it was customary to stack up the rags, after being duly moistened, in heaps, so that they became partially fermented, by which means the gummy and resinous matters were rendered soluble in water. The rags were then treated in wooden mortars and beaten for at least twenty-four hours by heavy stampers actuated from a waterwheel.

The stamping process was superseded at some period prior to 1770 A.D., the exact date being unknown, by the introduction of a machine provided with a cylinder fitted with sharp steel blades for tearing the rags into pieces. This machine was invented and first used in Holland, and even at the present day the "Hollander," as it is called, finds much employment in the beating of rags. The use of this machine marked an important epoch in the development of the paper trade.

The possibility of making paper by machinery early engaged the attention of manufacturers, and the names of Robert, Didot, Gamble, Fourdrinier, and Donkin can never be forgotten in connection with this fascinating subject.

Louis Robert was manager of a paper-mill at Essones in France. In 1799 he devised a machine consisting of an endless wire-cloth passing between two rolls. This wire was stretched horizontally between two rolls *B*, *C* (Fig. 154), one of which, *B*, was fixed, the other, *C*, being adjustable in order that the wire could be stretched when necessary. The beaten pulp stored in a vat *D* was thrown up by a revolving fan *E* against a curved plate *F*, which distributed the pulp and water in an even stream upon the surface of the cloth *A*. As the wire-cloth travelled slowly forward the water fell through the wire, and the rolls *G* removed a further amount from the wet sheet. The wet sheet was reeled up

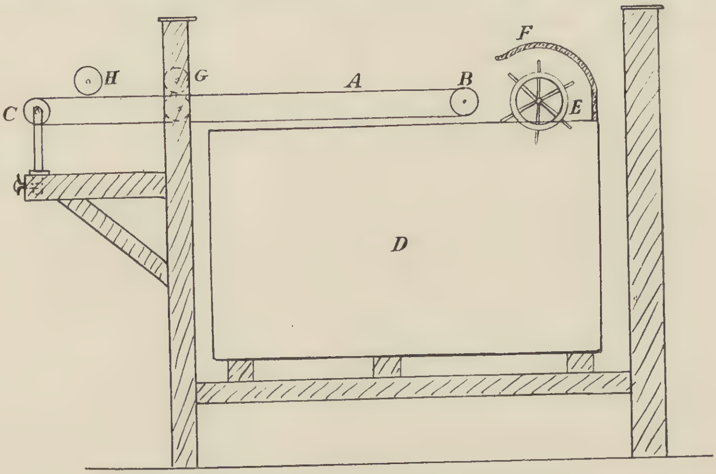


Fig. 154.—First Paper-machine (1802).

on a receiving roll *H* until a sufficient length had been obtained. The roll *H* was then removed, the paper unwound, passed through some press-rolls, and hung up to dry.

In 1800, Gamble, having secured from his brother-in-law, Didot, the patent rights of Robert, who was employed by Didot, came to England and interested Messrs. Fourdrinier in the machine. These gentlemen at first placed the construction of the machine in the hands of Messrs. Hall at Dartford, but subsequently engaged Mr. Bryan Donkin, one of the apprentices, to undertake the work at a factory in Bermondsey. In 1807 the first Fourdrinier machine was patented and erected at Two Waters Mill, Hertfordshire. The arrangements were very crude and primitive, but some encouraging results were obtained.

The mixture of pulp and water kept in a state of agitation flowed from a small vat *A* (Fig. 155) through a pipe on to the endless wire-cloth *B*, which was fitted with a suitable deckle *C*. The wet sheet of paper, from which a considerable quantity of water had been removed, was passed through squeezing-rolls *D*, so that more water might be taken out, this latter operation being still further assisted by the travelling-felt *E*, which also improved the firmness of the wet paper. After passing through couch-rolls *F*, the paper was pressed by rolls *G* and wound up on a separate reel *H*.

The energy of Donkin is displayed in the fact that during the years 1804 to 1851 his firm constructed no less than 190 machines.

Improvements followed rapidly, one after the other, directly the Fourdrinier machine became a commercial success. An exhaustive account of these may be found in the Report of the Jurors of the Great Exhibition of 1851,

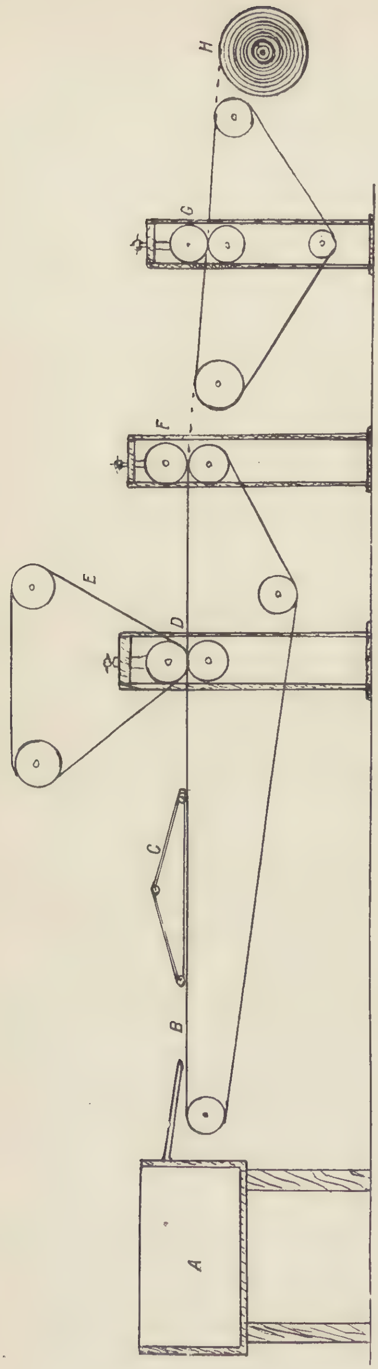


Fig. 155.—Donkin's First Fourdrinier Machine (1807).

but the chronology which forms part of this chapter makes a brief reference to them.

The early years of the nineteenth century were further rendered memorable to the paper trade through the discovery of bleaching-powder by Tennant, and the manufacture of soda by Leblanc, which enabled paper-makers to utilise vegetable fibres other than rags. Towards the middle of the nineteenth century, esparto, straw and wood were treated successfully for the manufacture of paper pulp by Routledge in 1860, who studied esparto, by Keller in 1840, who invented the process for manufacturing mechanical wood pulp, and Tilghmann in 1866, who patented a method for producing sulphite wood pulp.

The repeal of the duty on paper in 1860 gave a further impetus to the trade, and developments since that date have been proceeding by leaps and bounds.

The developments since the year 1860, which date may be regarded as the commencement of almost a new era in the paper trade, have proceeded along very definite lines, and it would not be a difficult matter to classify them under two or three headings, as, for example:

(1) The introduction of fibrous materials for paper-making, other than rags, and the starting up of new industries for the supply of pulp, chiefly manufactured from wood.

(2) The improvements in the mechanical construction of the paper-machine, which have been little short of marvellous.

(3) The invention of auxiliary plant and machinery for the treatment of raw fibre.

(4) The discovery of new applications of paper pulp in the direction of box-boards, roofing, &c.

(5) The invention of methods for utilising waste products, thereby lessening the cost of production.

These developments are more specifically mentioned in the Chronology.

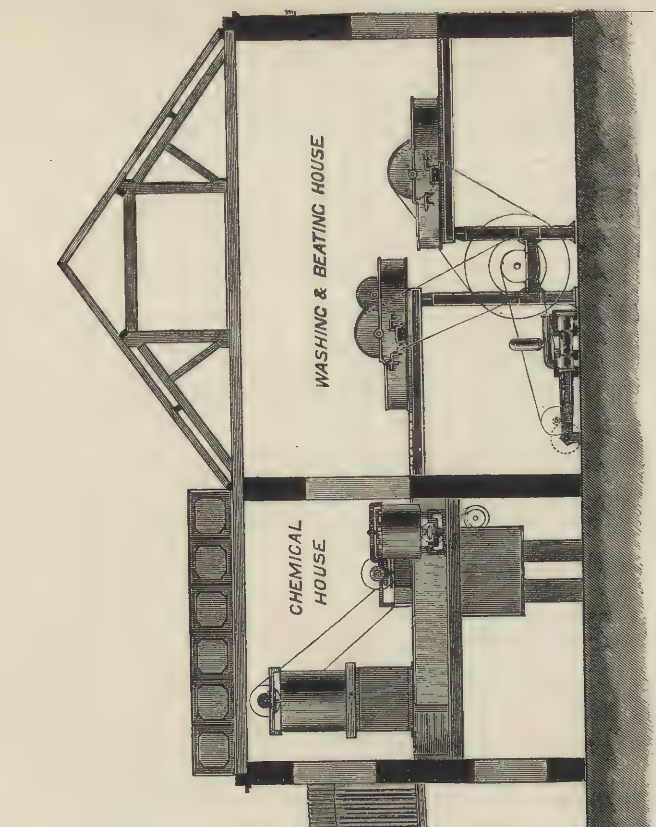


Fig. 156.—Sectional View of Paper-mill, showing Arrangements for Preliminary Treatment.

Chronology.

Some leading Dates in the History of Paper.

PERIOD PRIOR TO THE ERECTION OF THE FIRST PAPER-MILL IN ENGLAND.

Origin of paper unknown. Chinese probably familiar with some form of paper centuries before the utilisation of Papyrus.
1000 B.C. Papyrus, palm leaves, parchment in use for preserving records.
200 A.D. Rice and bamboo used by Chinese for paper, in considerable quantity.
704. Arabs obtained a knowledge of cotton paper at capture of Samarkand.
1000. Manufacture of paper introduced by the Moors into Europe.
1049. Date of oldest MSS. in England printed on cotton paper.
1189. Paper-making appears to have been established at Herault in France.
1309. Register of the hustings Court at Lyme Regis printed on cotton paper (an early English document).
1320. Date of earliest known English MSS. printed on linen.
1340. Paper-making industry well established in Italy.
1390. Paper-mill erected at Nuremburg by Stromer.

PERIOD PRIOR TO THE INTRODUCTION OF THE PAPER-MACHINE.

1498. Paper-mill in existence in England (Hertfordshire). An entry in the Privy Purse expenses of Henry VII. "for a reward geven at the paper mylne, 16*s.* 8*d.*"
1562. A book of this date mentions a paper-mill at Fen Ditton, near Cambridge.
1588. A German named Spielman built a mill at Dartford, being afterwards knighted by Queen Elizabeth.
1640. Manufacture of wall-paper hangings.
1658. France the principal centre of paper-making, exporting large quantities of paper.
1711. Paper first taxed during reign of Queen Anne for war expenses.
1719. Reaumur suggested possibility of making paper from wood, by observations on the wasp's nest.
1757. Wove moulds first used by Baskerville for making paper on which to print his "Virgil."
1760. James Whatman established his paper-mill at Maidstone.
1765. Schaffers of Ratisbon published a book giving specimens of paper made from many varieties of substitutes for rags.
1770. (Approx.) Invention of the "Hollander" beating engine, for the disintegration of rags.
1774. Discovery of chlorine gas by Scheele.
1791. Manufacture of soda ash, process invented by Leblanc.
1792. Patent for bleaching rags taken out by Campbell.
1799. Manufacture of bleaching-powder, process invented by Tennant.
1799. First attempt to make paper on a continuous machine by M. Louis Robert, in France.
1801. M. Koops published an "Historical Account of Substances used for Paper-making," the book being printed on paper made from straw.

Period of Early Machine Improvements.

1807. Erection of the first Fourdrinier paper-making machine, at Boxmoor, Herts., by Donkin.
1807. Rosin size introduced by Illig.
1809. Dickinson devised a cylinder machine for boards, &c.
1821. Steam cylinders first used by Crompton for drying paper on the machine.
1823. Use of sulphate of lime in papers to give weight, complained of (Hansard, 232).
1826. Introduction of the dandy roll, by J. Marshall.
1828. Circular knives used by Crompton for slitting paper on the machine.
1830. Improvements in cylinder machine for the manufacture of boards.
1830. Barrett devised a plan for water-marking paper on the machine.
1830. Barrett invented the method of making rolls true by grinding them together, using water and emery for the purpose.
1834. Normand published his "Manual du fabricant de papiers," a treatise on paper-making.
1836. Vacuum boxes used on the Fourdrinier machine, introduced by James Brown, of Esk Mills.
1837. Reduction of duty on paper.

Period of Introduction of New Paper-making Fibres.

1840. Manufacture of mechanical wood-pulp by Keller.
1851. Straw used for paper-making.
1854. Manufacture of soda wood pulp by Watt and Burgess.
1856. The first aniline dye, mauve, introduced by Perkin.
1857. Gaine invented parchment paper.
1857. Use of skeleton drums for drying sized papers introduced by Stuart.
1859. Refining engine (Jordan's patent) used for treatment of pulp.
1860. Introduction of esparto grass, by Routledge, for printing and writing papers.
1860. Duty on paper totally abolished.
1866. Tilghmann's process for the manufacture of sulphite wood.
1877. "Porion" evaporator devised for the recovery of soda liquors used for boiling esparto and straw.
1877. Recovery of soda used in boiling straw and esparto.
1886. Invention of "multiple-effect" apparatus for soda recovery by evaporation in vacuum machines.

Improvements During the Period Subsequent to 1886.

1889. Introduction of the "cone" drive for paper-machines, by which the speed is more easily regulated.
1890. "Circular" strainers used for pulp- and paper-machines.
1890. Machines for the production of art papers.
1890. Machinery for "duplex and triplex" papers.
1890. High-speed "news" machines.
1894. Improvements in reeling machines.
1896. Edge runners generally superseded by "kneading" machines.
1896. Beaters introduced having separate mechanism for circulation of pulp.
1898. Apparatus for the continuous bleaching and washing of wood pulp.
1899. The use of electricity for motive power.
1902. The adoption of producer gas for motive power.

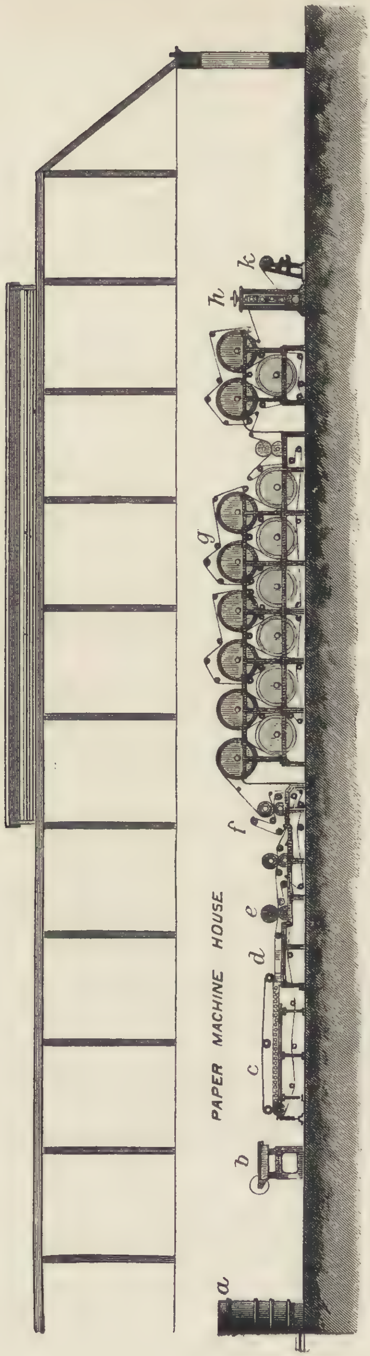


Fig. 157.—Sectional View of Paper-mill, showing the Paper-machine Room.

a, Stuff-chest ; *b*, Strainers ; *c*, Wire ; *d*, Suction-boxes ; *e*, Couch-rolls ; *f*, Press-rolls ; *g*, Drying cylinders ; *h*, Calenders ; *k*, Reeler.

Statistics.

The compilation of complete and accurate statistics in relation to the paper trade is probably a task beyond the power of the most ardent statistician.

The figures given in this chapter are those issued recently in connection with meetings of the Paper-makers' Association.

Statistics as to the Production of Paper in the United Kingdom.

(Presented by J. Y. Nuttall, Esq., at a meeting of paper-makers, October 28, 1903.)

Table LV.

Note.—*The production of Paper in the United Kingdom for* 1861 *was estimated by Mr. Chater at* 100,000 *tons.*

	1882.	1892.	1902.
Production of Paper in the United Kingdom:			
Weight	318,910 tons	483,380 tons	750,000 tons
Value	£8,438,000	£9,565,000	£11,026,400
Average price	£26 9s. per ton	£19 16*s*. per ton	£14 14*s*. per ton
Amount of wages	£1,189,600	£1,404,324	£1,649,214
Hands employed	25,370	28,742	30,786
Average individual wage per annum	£46 18*s*.	£48 15*s*.	£53 11*s*.

STATISTICS TABULATED BY THE PAPER-MAKERS' ASSOCIATION, OCTOBER 1903.

IMPORTS.

TABLE LVI.—*Total Weight and Value of Paper imported into the United Kingdom from Foreign Countries for Three Periods at Intervals of Ten Years.*

DESCRIPTION.	1882.		1892.		1902.	
	Weight.	Value.	Weight.	Value.	Weight.	Value.
	tons.	£	tons.	£	tons.	£
Printing or writing and envelopes	9,406	331,928	18,167	425,928	—	—
Pasteboard and millboard	30,126	319,841	59,144	453,586	—	—
Unenumerated	15,375	551,136	67,023	1,493,044	—	—
Paper, unprinted, on reels	—	—	—	—	57,373	739,316
,, ,, not on reels	—	—	—	—	128,746	2,300,299
,, printed or coated	—	—	—	—	8,597	545,514
Strawboard or millboard	—	—	—	—	100,983	695,642
Wood-pulp board	—	—	—	—	27,799	256,903
	54,907	1,202,905	144,334	2,372,558	323,498	4,537,674
IMPORTS OF RAW MATERIALS:						
Linen and cotton rags	21,200	303,349	23,032	214,065	18,692	173,732
Esparto	180,849	1,281,105	212,967	1,029,901	198,292	717,854
Pulp of wood	—	—	190,946	981,025	525,799	2,398,215
Other materials	70,745	502,973	26,367	216,314	14,656	96,972
	272,794	2,087,427	453,312	2,441,305	757,439	3,386,773

TABLE LVII.—*Total Weight and Value of Paper imported into the United Kingdom from Foreign Countries during the Five Years* 1898–1902.

Description.	1898.		1899.		1900.		1901.		1902.	
	Weight.	Value.	Weight.	Value.	Weight.	Value.	Weight.	Value.	Weight.	Value.
	tons.	£	tons.	£	tons.	£	tons.	£	tons.	£
Unprinted:										
Foreign	145,769	2,495,824	149,652	2,570,020	181,839	3,011,943	173,484	2,869,394	—	—
British	314	3,471	4,596	47,916	9,103	101,158	9,220	96,212	—	—
Printed or coated:										
Foreign	4,673	299,305	5,474	344,638	6,134	408,673	6,801	420,746	—	—
British	22	1,967	17	1,465	25	1,650	16	1,165	—	—
Strawboard millboard:										
Foreign	86,720	602,963	87,175	585,532	95,957	662,490	101,435	736,328	—	—
British	166	629	1,568	12,432	172	1,568	63	529	—	—
Paper on reels:										
Foreign	—	—	—	—	—	—	—	—	51,065	672,891
British	—	—	—	—	—	—	—	—	6,308	66,425
Paper not on reels:										
Foreign	—	—	—	—	—	—	—	—	127,242	2,283,874
British	—	—	—	—	—	—	—	—	1,504	16,425
Printed or coated:										
Foreign	—	—	—	—	—	—	—	—	8,569	543,160
British	—	—	—	—	—	—	—	—	28	2,354
Strawboard millboard:										
Foreign	—	—	—	—	—	—	—	—	100,836	694,248
British	—	—	—	—	—	—	—	—	147	1,394
Wood-pulp boards	12,893	126,025	16,837	162,075	29,396	224,958	23,045	217,860	27,799	256,903
	250,557	3,530,184	265,319	3,724,078	322,626	4,412,440	314,064	4,342,234	323,498	4,537,674
IMPORTS OF RAW MATERIALS:										
Linen and cotton rags	20,559	193,803	20,426	174,801	16,189	158,061	15,922	146,753	18,692	173,732
Esparto	197,341	768,779	207,604	806,354	200,280	800,498	193,937	802,463	198,292	717,854
Pulp of wood	404,842	1,894,395	415,113	1,989,703	487,742	2,617,789	448,455	2,406,084	525,799	2,398,215
Other materials	18,701	127,728	16,783	107,871	20,113	112,720	16,446	98,056	14,656	96,972
	641,443	2,984,705	659,926	3,078,729	724,324	3,689,068	674,760	3,453,356	757,439	3,386,773

EXPORTS.

TABLE LVIII.—*Total Weight and Value of Paper exported from the United Kingdom to Foreign Countries and British Possessions for Three Periods at Intervals of Ten Years.*

Description.	1882.		1892.		1902.	
	Weight.	Value.	Weight.	Value.	Weight.	Value.
	tons.	£	tons.	£	tons.	£
Writing or printing and envelopes :						
Foreign . .	4,296	258,151	7,020	282,810	11,106	368,325
British . .	16,387	745,096	27,336	848,748	26,960	753,964
Pasteboard, millboard, including playing-cards :						
Foreign . .	447	19,931	279	13,123	394	15,790
British . .	876	30,138	868	38,441	1,492	52,789
Unenumerated :						
Foreign . .	2,292	123,742	2,207	120,176	2.671	123,124
British . .	4,950	127,967	5,973	127,906	6,364	137,208
Bags :						
Foreign . .	—	—	—	—	20	457
British . .	—	—	—	—	1,376	27,029
	29,248	1,305,025	43,683	1,431,204	50,383	1,478,686
Hangings :						
Foreign . .	1,373	79,160	994	60,989	1,129	79,581
British . .	2,077	110,087	1,911	87,301	2,581	114,437
	3,450	189,247	2,905	148,290	3,710	194,018

TABLE LIX.—*Total Weight and Value of Paper exported from the United Kingdom to Foreign Countries and British Possessions during the Five Years* 1898–1902.

DESCRIPTION.	1898.		1899.		1900.		1901.		1902.	
	Weight.	Value.	Weight.	Value.	Weight.	Value.	Weight.	Value.	Weight.	Value.
Writing or printing and envelopes:	tons.	£	tons.	£	tons.	£	tons.	£	tons.	£
Foreign . .	7,871	282,379	8,376	288,796	10,967	365,118	9,120	325,147	11,106	368,325
British . .	28,771	639,371	20,670	594,690	26,881	758,637	26,722	770,131	26.960	753.964
Pasteboard, millboard, cardboard, playing-cards:										
Foreign . .	263	11,319	351	14,669	382	13,637	342	17,204	394	15,790
British . .	1,565	43,862	1,422	43,938	1,422	43,938	1,752	57,879	1,492	52,789
Unenumerated:										
Foreign .	2.620	125,628	2,756	130,855	2,808	137,369	2,767	132,167	2,671	123,124
British . .	7,088	136,912	8,656	154,616	7,406	155,987	6,870	143,691	6,364	137.208
Bags: Foreign . .	—	—	—	—	—	—	12	373	20	457
British . .	—	—	—	—	—	—	1.360	27,184	1,376	27,029
	48,178	1,239,471	42,231	1,227,564	49,866	1,474,686	48.945	1,473,776	50,383	1,178,686
Hangings: Foreign . .	1,387	89,167	1,557	96,583	1,235	83,249	1,164	83,186	1,128	79,581
British . .	2,640	103,321	2,742	99,777	1,976	87,127	2,302	111,615	2,580	114.437
	4,027	192,488	4,299	196,360	3,211	170,376	3,466	194,801	3,708	194,018

CHAPTER XVII

A DICTIONARY OF CHEMICAL TERMS

Abies.—A genus of trees belonging to order *Pinaceæ*, comprising spruce, larch, silver fir, &c., otherwise known as conifers, or cone-bearing trees, which are used in the manufacture of wood pulp.

Acetate of lead (*Sugar of lead*).—A substance prepared by dissolving ordinary litharge in acetic acid. When added to pulp in a beating-engine, followed by a solution of bichromate of potash, a bright yellow precipitate is produced which colours the fibres. The precipitate is known as chrome yellow, or canary yellow.

A filter paper impregnated with acetate of lead turns black or brown when brought into contact with sulphuretted hydrogen. This fact is taken advantage of in testing pulp and paper for traces of sulphur and sulphur compounds.

Acetic acid.—A liquid of 1·0553 specific gravity, having a strong pungent odour. Prepared by fermentation of alcohol, and also by the dry distillation of certain hard woods, such as oak, beech, and elm. Recommended by Lunge for use in bleaching paper pulp.

Acetone.—A substance prepared from calcium acetate, which latter is obtained by passing the products of the dry distillation of suitable woods into milk of lime. The acetone is used in large quantities for the manufacture of celluloid.

Adansonia.—The inner bark of the baobab, or monkey-bread tree, found on the west coast of Africa. The bast fibre contains a high proportion of cellulose. Tried many years ago for paper-making, but abandoned.

Adipo-cellulose.—A term applied to the complex cellulose substance which forms the cuticular tissue of cotton, straw, esparto and other fibrous plants.

Agalite.—Finely ground talc, possessing a good colour. Used as a loading for papers.

Agave (*Agave americana*) or **Aloe.**—A plant yielding fibres suitable for paper-making. Sisal cord or string, is manufactured from a Mexican variety of agave.

Alfa.—(See *Esparto.*)

Alkali.—A term applied in commerce to the carbonates of soda and potash; and to the hydrates, the latter being designated caustic alkalies. (See *Soda* and *Potash.*)

Alkali-cellulose.—The compound obtained by treating cotton or wood cellulose with concentrated solution of soda; used for the manufacture of viscose.

Alkali waste.—A residue of impure calcium sulphide produced in the manufacture of soda.

Alkaline solution.—Term applied to any solution which exhibits properties peculiar to alkalies, *e.g.*, turning litmus test paper blue.

Aloe.—(See *Agave.*)

Alum.—A common trade term for sulphate of aluminium. The more complex sulphates of aluminium, potash, and iron, &c., are also known as alums.

Alum cake.—(See *Aluminium sulphate.*)

Alumina.—The oxide of aluminium prepared by strongly igniting hydrate of alumina in a crucible. A white amorphous powder.

Aluminate of soda.—Obtained by dissolving freshly precipitated hydrate of alumina in caustic soda. Can be used in the process of rosin sizing.

Alumine.—A trade name for a loading used in America consisting chiefly of sulphate of lime with a small proportion of sulphate of alumina. Said to be well retained by paper.

Aluminium hydrate.—A bulky gelatinous precipitate produced when ammonia is added to a soluble aluminium salt. If ammonia is added to the solution obtained by extracting paper with hot water, the formation of a gelatinous precipitate indicates the presence of alum salts.

Aluminium sulphate.—An important material used in the sizing of paper. Added to animal size it acts as a preservative. Added to rosin size it precipitates the rosin upon the fibres in the beating-engine. Prepared commercially by the action of sulphuric acid on clays or bauxite. If the whole mass is dried down the product is sold as *alum cake.* If the solution is filtered free from the insoluble residue, silica, and evaporated, the product is sold as *aluminium sulphate.*

Ammonia.—Commercially known as Liquor Ammoniæ, or *spirits of hartshorn*, a liquid of strong piercing odour. Used in paper-making for dissolving casein, an adhesive applied in the manufacture of art and coated papers; used as a laboratory reagent for detecting alum salts in paper.

Amyloid.—A substance obtained by acting upon cotton or cellulose with thirty times its weight of sulphuric acid (density 1·60). The syrup produced is poured into water, and the precipitate which results dried. The horny mass found is amyloid. The change produced when paper is passed through acid for the manufacture of *parchment* is the formation of this *amyloid* on the surface of the paper.

Aniline.—A coal-tar product, used as a basis for aniline dyes. Originally prepared from indigo, from which the name has been derived (Portuguese = anil).

Aniline sulphate.—The compound obtained by treating aniline with sulphuric acid. Used for detecting mechanical wood and esparto in papers.

Animal size.—A term applied to glue or gelatine used in sizing high-class papers. (See *Gelatine.*)

Annaline.—A trade name for sulphate of lime, used as a loading. (See *Sulphate of lime.*)

Antichlor.—A term applied to substances used for removing traces of bleach from pulp, such as hyposulphite of soda, sodium sulphite, and hydrogen peroxide (which see).

Aqua fortis.—(See *Nitric acid.*)

Arsenious acid.—A soluble compound of arsenic used for determining the strength of bleaching-powder.

Asbestos.—A soft fibrous mineral found in Italy and Spain. Can be worked up into paper with varying proportions of pulp for the manufacture of incombustible goods. Ground into powder forms a loading or filling for paper under the name *asbestine.*

Ash.—A term applied to the mineral residue left on igniting a piece of paper.

Aspen.—A species of poplar, the light coloured wood of which yields a very white mechanical pulp, and a light porous chemical pulp.

Auramine.—A yellow coal-tar colour much used for giving yellow shades to paper.

Available chlorine.—The chlorine in bleaching-powder which effects the bleaching of pulp, present in a normal powder to the extent of 36 per cent.

Bagasse.—The stalk of the sugar-cane, available as a paper-making fibre.

Balsam fir.—A coniferous tree very plentiful in North America, and used in limited quantities for manufacture of mechanical pulp.

Bamboo.—Any species of the genus *Bambusa.* A giant grass often reaching a height of forty feet, found in the tropical regions of the Eastern Hemisphere. Suggested in 1875 by Routledge as an excellent material for paper-making.

Baobab.—(See *Adansonia.*)

Barium sulphate.—A heavy mineral known as *blanc fixe*, *heavy spar*, having a specific gravity of 4·4.

When ground to powder, used as a filler for paper, and as an ingredient in *satin white* used for coated papers. Can be prepared artificially by adding sulphuric acid to a soluble barium salt, such as barium chloride.

Barytes.—Ordinary name of barium sulphate.

Bass wood.—Yields a good soda pulp, but not much used at present.

Bast.—A term applied to the inner bark of plants which forms the material available for paper-making. Flax, hemp, jute and ramie are typical bast-fibre plants.

Bauxite.—A natural ore containing 32 per cent. of alumina and 28 per cent. of oxide of iron, used for the manufacture of alum cake and sulphate of alumina.

Beech.—A tree with hard tough wood, not used in any quantity for paper-making.

Berlin blue.—Another name for Prussian blue.

Benzo-purpurine.—An aniline dye similar to Congo red, yielding a bright colour, unaffected by dilute mineral acids. A useful stain for microscope work.

Bisulphite of lime.—The chemical used for the manufacture of sulphite wood pulp. Prepared by passing sulphurous acid gas into a solution of milk of lime.

Black liquor.—The spent caustic lyes run off from the digesters used for the preparation of soda wood pulp, esparto and straw pulps.

Blanc fixe.—(See *Barium sulphate.*)

Bleaching-powder.—Used for bleaching pulp and fibres of every description. A dry pulverulent powder of pungent odour prepared by exposing dry powdered quicklime to chlorine gas. It yields a clear solution of *chloride of lime*, when extracted with water.

Borax.—A substance found in nature as *tinkal*, known chemically as sodium biborate. Used as a solvent for casein in the manufacture of art papers.

Calcium carbonate.—Commonly known as carbonate of lime, or chalk. Occurs in nature in the form of marble, Iceland spar and limestone. Produced in large quantities as a waste product when soda and *recovered ash* (which see) are converted into caustic soda.

Calcium hydrate.—Commercially known as slaked lime. Used for the manufacture of clear lime-water required for the softening of hard boiler feed-waters; used for the conversion of soda and recovered ash into caustic soda.

Calcium hypochlorite.—The active principle of bleaching-powder, which yields up the available chlorine for bleaching.

Calcium sulphate.—Used as a filler for papers. Known under several trade names according to the method of preparation, as follows: Gypsum, powdered gypsum, sulphate of lime, powdered plaster, terra alba, satinite, mineral white.

Chemical composition of all these preparations, some natural, others

artificial, is that of ordinary calcium sulphate. Hard waters contain appreciable quantities in solution.

Calcium sulphite.—A substance insoluble in water, produced by passing sulphurous acid gas into milk of lime, or lime-water. It is formed as an intermediate product in the preparation of bisulphite liquor, the gas converting it into a soluble bisulphite of lime. Used also as an antichlor. (See *Antichlor.*)

Canada balsam.—A pale-coloured oleo-rosin obtained from the American silver fir. Used for mounting microscopic objects, in preparing permanent slides.

Canary yellow.—(See *Acetate of lead*). Known as chrome yellow, or chromate of lead.

Cannabis sativa.—Hemp.

Carbo-hydrates.—A class of important organic substances containing the chemical elements, carbon, hydrogen, and oxygen, the two latter being always present in the proportions which are found in water. Such are sugars from cane, milk and fruit; starch, dextrin, cellulose.

Carbonate of lime.—(See *Calcium carbonate.*)

Carbonate of soda.—(See *Soda.*)

Casein.—An albuminous substance obtained from milk by the action of sulphuric acid. Insoluble in water, but soluble in weak solutions of ammonia, soda and borax. Used for sizing of papers, and as an adhesive in the manufacture of coated papers.

Catechu.—A dye-stuff obtained from certain species of *Acacia, Areca* and *Uncaria*, growing in India. Gives brown, olive, grey and black shades.

Caustic soda.—A powerful alkali prepared by boiling carbonate of soda with quicklime. Used for isolating cellulose or paper-making fibre from plants. Used under suitable conditions has little or no action upon cellulose. Dissolves animal fibres, such as silk and wool, readily. Converts cotton fabrics into the well-known mercerised cotton. Sometimes described briefly as *caustic*, or chemically as *sodium hydrate.*

Cellulose.—The chemical substance, more familiar as *fibre*, obtained when vegetable substances are treated with caustic soda or other suitable reagents in such a manner as to dissolve out all the resinous and non-fibrous constituents. (See special chapter on *Cellulose.*)

Celluloid.—A cellulose derivative obtained by mixing camphor with certain nitrates of cellulose. (See chapter on *Cellulose.*)

China-clay.—A substance, known also as Kaolin, formed naturally by the weathering of felspathic rocks, and consisting of silicate of alumina. Specific gravity 2·3. Used as a loading for paper, particularly for common printings, also as the basis of the coating on art papers.

China grass.—A shrub similar to ramie, yielding exceedingly long fibres. Sometimes called Rhea (*Boehmeria nivea*).

Chloride of lime.—(See *Bleaching-powder.*)

Chlorine.—A greenish gas of pungent odour prepared by heating hydrochloric acid (spirits of salts) with manganese dioxide. Absorbed by dry lime it yields bleaching-powder. Fibres previously boiled in caustic soda are readily bleached when exposed to chlorine gas.

Chlorophyll.—The name given to the green colouring-matter of plants.

Chromate of lead.—(See *Canary yellow.*)

Chrome yellow.—(See *Canary yellow.*)

Coal-tar colours.—So called because the colours are *derived* from organic substances found in coal-tar.

Cochineal.—A dye giving a rose or scarlet colour prepared by drying cochineal

insects, which are found in Central America. Generally used in conjunction with ultramarine for correcting the tone of white papers.

Cocoanut fibre (*Cocos nucifera*).—Sometimes called Coir. Only used for matting, not being suitable for paper.

Collodion.—(See chapter on *Cellulose.*)

Colophony.—(See *Rosin.*)

Conifer.—A tree or shrub belonging to the order *Coniferæ*, so called because the fruit of the tree is a cone, as in the pines and firs.

Crotolaria juncea.—Botanical name for sunn hemp.

Cuprammonium.—A bluish coloured solution of copper oxide in ammonia, which has the property of dissolving cellulose. This property is taken advantage of in the preparation of "Willesden" waterproof paper and other products.

Cudbear.—A colouring-matter obtained by the action of air and ammonia on certain lichens. Very little used in paper-making.

Dextrin, or **British gum.**—Obtained by the action of boiling dilute sulphuric acid on starch; also obtained as one of the decomposition products of cellulose when the latter is oxidised by permanganate of potash. Used as a gum, or adhesive.

Diastase.—A peculiar nitrogenous substance which is capable of acting upon starch, converting it into sugar and rendering it soluble. Can be used for removing starch from rags.

Dicotyledon.—A botanical term applied to plants in which the seed on sprouting produces *two* seed leaves, such as beech, ash, pine, and conifers.

Dolomite.—A natural carbonate of lime and magnesia, used for the manufacture of bisulphite liquor required in the chemical wood-pulp industry.

Endogens.—A botanical term applied to plants in which the new wood is developed in the inner part of the stem. Palms, grasses, and sedges belong to this class.

Engine size.—A term sometimes applied to *rosin size.*

Eosin.—A dye-stuff obtained by the action of bromine on fluorescin dissolved in acetic acid. Gives a reddish shade, but is very fugitive when exposed to light.

Esparto (*Stipa tenacissima*).—A grass peculiar to Spain and Algeria pre-eminently suitable for magazine papers. On treatment with caustic soda it yields 45 per cent. of paper-making fibre.

Exogen.—A plant, the stem of which increases in thickness by the addition of layers externally. Exemplified by an ordinary tree, the section of which reveals this growth by the concentric rings.

Ferric chloride.—An iron salt used for testing the sizing qualities of a paper by methods due to Leonhardi and to Schluttig and Neumann. With tannic acid it produces a black ink spot on a sheet of paper. With ferrocyanide of potassium it gives *Prussian blue.*

Ferricyanide of potassium, or *Red prussiate.*—A substance used in the preparation of the pigment known as Turnbull's blue.

Ferrocyanide of potassium, or *Yellow prussiate.*—A substance which, mixed with ferric chloride, gives the well-known pigment *Prussian blue.*

Flax (*Linum usitatissimum*).—A plant which gives *linen.* Contains 75 to 80 per cent. of cellulose.

Fuchsine.—A commercial name applied to a red aniline dye known by such other names as magenta, rosaniline, &c.

Furfural.—The product of the treatment of oxycelluloses with hydrochloric acid. The yield of furfural obtained by treating fibres analytically with acid is a valuable measure of certain constituents in the fibre.

Fustic.—A colouring-matter obtained from the wood of the sumach tree (*Rhus cotinus*). With *tin salt* mordants it yields bright orange-yellow colours.

Gelatine.—A colourless transparent substance insoluble in cold water, used for tub-sizing the best qualities of rag paper. May be detected in even very dilute solutions by the addition of a few drops of tannic acid solution, when a flocculent precipitate forms more or less quickly. (See also *Glue.*)

Glucose.—Grape sugar, a carbohydrate, which can be obtained by prolonged boiling of cellulose with strong sulphuric acid. Commercially prepared from starch.

Glue.—A crude form of gelatine obtained by boiling down scraps of hide and bones. Used in sizing papers, in preparing enamel for coated papers.

Ground wood.—A term applied to wood ground into pulp by mechanical means. (See *Mechanical wood pulp.*)

Gypsum.—A natural sulphate of lime. When ground into a fine powder used as a filler for paper under various fancy names. (See *Calcium sulphate.*)

Hard water.—So called on account of the presence of carbonates of lime which cause *temporary hardness*, and sulphates of lime, which cause *permanent hardness*. The former can be removed by boiling, the latter is unaffected; hence the terms used.

Heavy spar.—(See *Barium sulphate.*)

Hemlock.—A hard red wood not very suitable for white papers, but yielding a pulp when treated chemically which can be used in limited quantities. Mainly applied to the manufacture of wrappers.

Hemp (*Cannabis sativa*).—A plant yielding fibre of great strength. It comes to the paper-mill in the form of canvas, sailcloth, ropes, &c., and passes through the usual operations. Mixed with cotton and linen rags makes an excellent paper. Used also for cable and insulation papers. Cannot be bleached readily to a good colour.

Hydro-carbons.—A class of organic compounds containing carbon and hydrogen united in varying proportions, of which the gases, naphthas, solid and liquid oils found in petroleum are well-known examples.

Hydro-cellulose.—A friable powdery substance obtained by exposing cellulose previously dipped in a dilute mineral acid to air. Paper dipped in weak sulphuric acid, or in moderately strong bleach liquor, and then warmed, is quickly destroyed on account of this change in constitution.

Hydrochloric acid.—Spirits of salt, prepared from ordinary salt. Occasionally used to hasten the process of bleaching paper pulp.

Hypochlorite of calcium.—(See *Bleaching powder.*)

Hyposulphite of soda.—A white deliquescent substance used as an antichlor (See *Antichlor*).

Indian red.—A red pigment obtained by grinding one of the many varieties of red ochre. Used chiefly in colouring wrappers and boards.

Iodine.—A solid crystalline substance of bluish steel colour. A solution of iodine in potassium iodide is of great value in the laboratory for testing sulphite liquors, presence of starch in paper, erasures and alterations on documents, for staining fibres for microscopic examination, &c.

Isinglass.—The purest form of gelatine obtained from the swimming bladders of certain fish.

Javelle water.—A bleaching liquid prepared by adding a solution of carbonate of potash to ordinary chloride of lime liquor. The clear liquid obtained after the sediment has settled down is convenient for bleaching small quantities of fibre experimentally, as there is no deposit of lime on the fibres, which sometimes occurs in the case of ordinary chloride of lime.

Jute (*Corchorus capsularis*).—An Indian plant, the fibre of which is used for manufacture of coarse sacking and bags, and gunny. Raw material used by paper-makers is the old gunny and sacking.

Kaolin.—(See *China-clay.*)

Larch or **Tamarack.**—A hard resinous wood, very plentiful in North America, but difficult to work up into pulp.

Lignified fibre.—A term applied to jute, wood, and other fibres in which a peculiar substance called *lignin*, present as the result of natural growth, is always found when the treatment has not been carried far enough to give a pure *cellulose*. Mechanical wood pulp is lignified fibre.

Lignin.—A non-fibrous substance, the composition of which has not been definitely settled, the product of natural growth in jute and wood principally. It is entirely removed from wood by adequate chemical treatment. The intimate association of *lignin* and *cellulose* in mechanically ground wood-pulp is the cause of decay and discoloration in many printing papers. Its presence is detected by the test with *aniline sulphate.*

Lignite.—A form of fossil wood, almost converted into coal, but not hard or black like the true coal.

Ligno-cellulose.—A term applied to the compound-celluloses which are present in jute and wood, the latter not being cellulose of the simple or normal type like cotton.

Lime.—Calcium oxide, or quicklime. A caustic powder obtained by roasting limestone or marble. Has many industrial uses in its application for the manufacture of cements, mortar, bleaching-powder, lime-water, sulphite liquor, &c.

Linen.—Term usually confined to the cuttings and rags received by the paper-maker. The *linen* fibres are the bast fibres of the *flax* plant.

Litmus.—A vegetable colouring-matter derived from *Roccella tinctoria*, used in chemistry to determine the acidity or alkalinity of a solution by its change to red or blue respectively.

Logwood.—The wood of *Hœmatoxylon campeachianum*, yielding a brownish red extract, used in colouring paper, for producing blacks and greys, as in needle papers, &c.

Lunar caustic.—Fused silver nitrate.

Magenta.—A red *aniline* dye much used in colouring paper to various shades of crimson, chemically known as Rosaniline hydrochloride.

Madder.—Root of *Rubia tinctorum*, yielding a variety of colours, such as red, pink, purple and chocolate, according to treatment. The well-known *Turkey red* is produced from madder.

Magnesia.—An oxide of magnesium similar to lime, which is an oxide of calcium. Occurs in nature combined with carbonic acid as carbonate, frequently associated with carbonate of lime. (See *Dolomite.*)

Magnesium silicate.—A compound occurring more or less pure in various forms, such as *agalite*, *asbestos*, *French chalk*, *talc*, most of which are used as fillers for paper.

Malachite green.—An aniline dye giving brilliant green shades.

Manila hemp (*Musa textilis*).—A plant found in the Philippine Islands. The fibre is strong and very suitable for ropes, which, when old, yield excellent paper pulp.

Mauve.—The earliest coal-tar colour, first manufactured by Perkin in 1856. Gives a beautiful purple shade.

Mechanical wood pulp.—Pulp prepared by grinding wood against stones in the presence of water. So called because the process is purely mechanical.

Megass.—Refuse sugar-cane.

Mercerised cellulose.—Cellulose treated cold with strong solutions of caustic soda. Used for the manufacture of *viscose.* (See *Viscose.*)

Methyl orange.—A dye very sensitive to acids, which turn it pink, and to alkalies which turn it yellow. Used in the laboratory for testing acids and alkalies.

Millon's reagent.—A special test solution prepared from mercury and nitric acid, which gives a rose-red coloration when brought into contact with gelatine, or papers sized with gelatine. Casein gives a similar reaction.

Mitscherlich pulp.—Chemical pulp prepared by cooking wood for forty-eight to sixty hours at a low pressure. Called after the name of the inventor.

Monocotyledon.—A botanical term applied to plants, in which the seed when sprouting produces *one* seed leaf, such as the palm, bamboo, esparto.

Mordant.—A substance, usually some metallic salt such as tin chloride, employed to precipitate the colour upon fibre, the colouring-matter being soluble when added to the pulp. Sulphate of alumina used for sizing paper acts as a mordant at the same time.

Muriatic acid.—Spirits of salt or hydrochloric acid.

New Zealand flax (*Phormium tenax*).—A plant yielding a high percentage of cellulose, but not used for paper-making.

Nitrate of iron.—A reddish coloured iron salt which, added to the pulp in the beating-engine, produces many shades of *cream* printing papers when used in small quantities, and *buff* coloured papers when used in greater quantities.

Nitric acid.—Aqua fortis.

Ochres.—Natural coloured clays varying in colour from burnt sienna to cream, the depth of shade being determined by the proportion of sesquioxide of iron present. Used for wrappers, sugar papers, boards, &c.

Oil of vitriol.—Sulphuric acid.

Orange mineral.—A manufactured pigment prepared by roasting carbonate of lead.

Oxalic acid.—An organic acid prepared commercially by fusing sawdust or wood chips with soda at a high temperature, and treating the product first with lime and then with sulphuric acid.

Oxycellulose.—A white powdery substance produced by the oxidation of cellulose, brought about, for example, by exposure of paper or linen dipped in strong bleach liquor.

Ozone.—A curious modification of *oxygen* prepared by passing sparks from an electric machine through oxygen. An energetic bleaching agent which is being gradually used commercially.

Parchment.—The skin of calf, sheep, or goat, specially prepared for writing purposes.

Parchment paper.—Prepared by dipping unsized paper into sulphuric acid of about 1·50 specific gravity and subsequently washing out all the acid.

Pearl ash.—Carbonate of potash.

Pearl hardening.—(See *Calcium sulphate.*)

Pecto-cellulose.—A compound cellulose found in certain fibrous plants, the composition and characteristics being little known.

Phloroglucine.—An organic substance prepared by the action of mineral acids on *phlorizin*, which occurs in the root-bark of certain trees. Used in testing papers for the presence of mechanical wood or lignified fibres.

Potassium bichromate.—A reddish substance used for precipitating the pigment canary yellow upon pulp, by its action on sugar of lead.

Prussian blue.—A blue pigment obtained by adding ferric chloride to a solution of yellow prussiate of potash. Colour discharged by alkalies.

Pyroxylin.—(See chapter on *Cellulose.*)

Ramie.—A plant found in India and China, somewhat difficult to treat. Gives long silky fibres having a fine lustre. Used for textiles, but too expensive for paper-making.

Recovered ash.—Crude carbonate of soda obtained by burning the black residues from the boiling of esparto and other fibres, the liquors having been first concentrated by evaporation.

Resin.—A term usually employed to designate the natural oxidised essential oils found in trees. Synonymous with rosin, though the latter term is often specially applied to *colophony*, the particular resin of the southern pine, which is the residue from the distillation of turps.

Resinate of aluminium.—The precipitate formed by adding alum solution to rosin size. This precipitation takes place when paper is sized in the beating-engine.

Rhea.—(See *China grass.*)

Rosin.—(See *Resin.*)

Rosin size.—A compound formed by boiling powdered rosin with carbonate of soda. Soluble in water, and used for sizing paper in the beating-engine.

Safranine.—A red aniline dye sensitive to light, used for pink papers.

Sapwood.—The outer rings of the tree, of comparatively recent growth, called the *alburnum*, containing the sap, in contradistinction to the heart-wood.

Schweitzer's reagent.—An ammoniacal solution of cupric oxide, capable of dissolving cellulose. Used in the manufacture of "Willesden" paper. A useful microscope reagent. (See *Cuprammonium.*)

Sisal hemp.—(See *Agave.*)

Size.—(See *Rosin size.*)

Smalts.—A pigment obtained by grinding to powder a blue glass, the colour of which is due to the presence of cobalt silicate.

Soapstone.—(See *Magnesium silicate.*)

Soda.—Name commonly applied to carbonate of soda. One of the most important chemicals for industrial purposes, manufactured from common salt. When causticised with quicklime it is converted into caustic soda, which latter substance is required for the digestion of fibres. Soda is used in the paper-mill for the preparation of rosin size, for softening water, and for manufacture of caustic soda.

Soda pulp.—Pulp prepared by digesting wood with caustic soda. The name is frequently misapplied to pulp prepared by the *sulphate* process. (See *Sulphate process.*)

Soda recovery.—A term applied to the process by means of which the caustic soda black liquors run off from the boiled pulp are evaporated, incinerated and treated so as to recover the caustic soda in a form capable of being used over again.

Sodium chloride.—Common salt.

Sodium hydrate.—Caustic soda.

Sodium hypochlorite.—Also known as Labarraque's disinfectant, or *chlorinated soda.* Prepared by adding carbonate of soda to bleach liquor and allowing the precipitate to settle. Useful for laboratory purposes as a bleach liquor because no insoluble deposits are found on the fibre after bleaching.

Sodium hyposulphite.—Used as an *antichlor* to kill traces of bleach, but now being superseded by other substances which do not tend to deposit sulphur in the fabrics or fibres treated.

Sodium sulphite.—An efficient "antichlor" or bleach killer, which removes any traces of chloride of lime without the formation of new residues likely to injure the pulp.

Spent liquor.—The waste lyes run off from digesters after the fibre has been boiled. Soda lyes can be recovered. Sulphite lyes are usually thrown away.

Spruce.—The tree, *par excellence*, for the manufacture of chemical and mechanical wood pulp. Easily yields a strong fibrous pulp when treated by the sulphite process.

Starch.—Used as a sizing material in blottings, and to improve the surface and finish of high-class papers. May be detected in paper by its blue reaction with iodine. Quantitative estimation in paper very difficult.

Stipa tenacissima.—(See *Esparto.*)

Straw.—The stem of cereals, such as oat, wheat, barley, maize, &c. Gives a pulp of short fibre, which adds to the hardness of the paper.

Sugar of lead.—(See *Acetate of lead.*)

Sulphate of alumina.—(See *Aluminium sulphate.*)

Sulphate wood pulp.—Often miscalled *soda pulp.* Prepared by digesting wood with a mixture of sulphate of soda, caustic soda, and sulphide of soda.

Sulphite liquor.—The solution of calcium bisulphite and free sulphurous acid used for the preparation of sulphite wood pulp.

Sulphite wood pulp.—Pulp prepared by the sulphite process.

Sulphur.—The familiar substance which is required for the manufacture of sulphite liquor. Each ton of pulp requires the burning of about 280 to 350 lbs. of sulphur into sulphurous acid gas.

Sulphuric acid.—The most important acid of commerce. A heavy colourless liquid with specific gravity 1·84, and boiling-point of 338° C. Used in the paper-mill merely for cleaning the machine wire, and occasionally for hastening the bleaching of pulp. Its action upon cellulose varies with the degree of strength of acid and the temperature at which the action takes place. (See chapter on *Cellulose.*)

Sulphurous acid, or **Sulphur dioxide.**—A gas prepared commercially by burning sulphur in a carefully regulated supply of air. In the manufacture of sulphite liquor, the gas is brought into contact with moistened limestone, and the gas unites with the lime and water. The gas itself is very soluble in water, and exercises a powerful bleaching action.

Sunn hemp (*Crotalaria juncea*).—An Indian plant used for bagging and cordage, Not used as a paper-making fibre in any quantity.

Sylvic acid.—Also called Abietic acid, the principal constituent of rosin or colophony.

Talc.—A soft transparent mineral, which can be split into thin laminæ. When finely ground used as a filler for paper. (See *Magnesium silicate.*)

Tamarack.—(See *Larch.*)

Tannic acid.—An organic acid obtained from the bark and wood of many trees, such as oak, sumach, mimosa, quebracho. Used as a test for animal size in paper.

Terra alba.—A fancy name for a precipitated form of sulphate of lime. A substance used as a loading for paper.

Tracheids.—The wood fibres of coniferous trees, such as spruce and fir, characterised by curious pitted cells readily detected in sulphite pulp when examined under the microscope.

Ultramarine.—A double silicate of sodium and aluminium prepared by fusing kaolin, sulphate of soda, carbonate of soda, and charcoal in a crucible, and roasting the green substance obtained with sulphur. The blue mass formed is powdered, washed and dried, and sold as ultramarine.

Vegetable parchment.—(See *Parchment paper.*)

Venetian red.—A native ochre of varying shades of red. Artificial varieties are also prepared from sulphate of iron. Used for colouring paper, principally wrappers and boards.

Viscose.—A soluble form of cellulose. (See chapter on *Cellulose.*)

Vitriol.—(See *Oil of vitriol.*)

Vitriol blue.—Sulphate of copper.

Waste liquors.—(See *Spent liquors.*)

Wood vinegar.—Crude acetic acid prepared by the distillation of wood.

Zinc chloride.—Used for the preparation of vulcanised paper and board, acting upon cellulose in a manner similar to sulphuric acid. It is also a useful reagent for the microscopic examination of fibres.

CHAPTER XVIII

A GLOSSARY OF VARIOUS PAPERS

WITH BRIEF NOTES AS TO ORIGIN OF SAME, AND USE OF THE PAPERS

The author will be glad of any additions or corrections supplied by readers.

Air-dried browns.—Brown papers carefully made, and slowly dried by exposure to air, which ensures great strength and elasticity.

Albumenised.—Paper used in photography; coated with albumen from the white of egg mixed with ammonium chloride, and then treated with silver salts sensitive to light.

Ammunition.—Hard strong papers made of wood, hemp, or gunny, used for cartridges and other purposes relating to ammunition.

Animal-sized.—A term applied to any paper which has been sized with gelatine.

Antique.—A light bulky paper having a soft velvety feel, used largely for novels and standard works of fiction. Made of esparto *per se*, or mixed with chemical wood pulp, uncalendered, and containing no loading as a rule.

Anti-acid manila.—A hard strong paper made of hemp, or sometimes wood pulp, used for insulating purposes, telephone wires, &c., and guaranteed free from any acid reaction.

Antiquarian.—The largest hand-made sheet known, measuring 53 inches by 31. It is said that this name is due to the fact that the Society of Antiquaries of London required a sheet of extra large size for a special purpose.

Art.—A paper, usually made of esparto and wood pulp, coated on both sides with a mixture of glue and some mineral, such as china-clay, and highly glazed. Used for the printing of half-tone blocks. Origin of name doubtful, but probably derived from its connection with the new "art" of process printing.

Asbestos.—A paper containing a large proportion of fibrous asbestos, used for the manufacture of theatre curtains, screens, insulation papers, &c.

Azure-laid.—A term by long custom applied to certain high-class writings of a particular shade of blue, made on a "laid" mould or wire. (See *Laid.*)

Azure-wove.—A similar term applied to blue paper made on a "wove" mould. (See *Wove.*)

Atlas.—A drawing paper measuring 34 inches by 26. Name supposed to be due to the use of a water-mark in the early days of paper-making, showing the figure of Atlas bearing the world on his shoulders.

Bag.—A term applied to any papers used for making bags.

Bank.—A term applied to high-class machine writings, which are very strong and thin. Made from rags, or wood pulp, beaten for eight to nine hours. Paper is similar to *loan*, but not quite so heavy or transparent. Name probably due to the paper first finding favour amongst bankers and commercial men.

Bible.—A strong thin paper, used for Bibles originally, in which *opacity* is a chief characteristic, obtained by careful boiling and beating of rag. Wood pulp now used in cheaper qualities.

Biscuit.—A term originally applied to papers used for packing biscuits, particularly thin sulphite pulp papers glazed on one side. The paper now used for wrapping all kinds of dry goods.

Blotting.—An unsized highly absorbent paper, used as the name implies. Best qualities made from soft old muslin rags, sometimes tendered by chemical treatment. Cheaper qualities from soft wood pulps.

Blue print.—A paper sensitive to light, used by engineers for copying tracings of machinery, &c. Prepared by floating white paper on a solution of yellow prussiate of potash (potassium ferrocyanide) and peroxide of iron.

Book end.—A term applied to the papers used for finishing off the insides of the covers of books. Of all qualities and colours.

Boot boards.—Specially hard boards prepared from waste papers and tough fibre, used for the insoles and heels of boots. Frequently toughened by addition of pulped leather clippings.

Box boards.—Used for box-making of all kinds, and manufactured from mechanical wood pulp, old waste papers, hemp, &c., on cylinder machines or wet press machines.

Box enamels.—White or coloured coated papers of the cheapest description used for covering boxes. Coated on one side only, and very highly glazed.

Bowl.—Special soft paper used for making paper-rolls, or *bowls*, required in the supercalender machine. Made solely of or from mixtures of soft rag, wool, asbestos, beaten quickly and not sized.

Bristol boards.—High-class cardboards first made at Bristol, from which the name is derived.

Browns.—Brown wrapping paper of every description.

Buff printings.—Ordinary printing paper buff-coloured, the tone being produced generally by iron salts added to the pulp in the beating-engine.

Butter.—Papers used for wrapping butter, lard and similar greasy goods. Usually some cheap form of *vegetable parchment*, or its substitute, *imitation parchment* (which see).

Calf.—A more or less embossed stout paper, coloured to fancy, made to imitate leather. Used for bookbinding.

Caps.—Thin wrapping papers used in retail shops; a general term for such papers. Origin of name uncertain.

Carbon.—Used for the production of duplicate copies of bills, invoices, and similar documents. Prepared by surfacing thin tissues with a mixture of lampblack and fatty substances such as lard.

Carbolic.—Paper impregnated or surfaced with a mixture of stearin and carbolic acid. Used as a wrapping paper for food.

Cardboards.—A general term applied to thick stiff paper, or to the stiff board obtained by pasting layers of paper over one another.

Carpet felt.—A brown soft thick spongy kind of paper used for inserting between floor-boards and carpet. Prepared from common waste paper and similar residues on an ordinary machine.

Carriage panels.—Hard stiff boards made from waste paper, &c., very heavily pressed and rolled. Frequently hardened and stiffened by being *vulcanised* (which see).

Carton pierre.—A French term meaning *stone card.* An imitation stone prepared by moulding pulped waste paper into various shapes under great pressure. Used for theatrical properties and similar objects.

Cartridge.—A term now used to denote ordinary qualities of drawing papers

made from rag or wood pulp, being strong, tough and opaque. Word originally confined to paper used for cartridge-making, but now somewhat loosely applied.

Casings.—A term applied to a certain size of packing paper. Exact origin of word uncertain, probably due to the paper having been used for lining purposes originally.

Cassie.—A term once used to describe the few outside sheets of a ream of good paper; from the French *casser*, to break or waste.

Chart.—A strong tub-sized rag paper of medium surface, used for charts and maps. Inferior qualities made from esparto and wood, specially treated so as to stretch as little as possible.

Chromo.—A heavily coated paper used in chromo-lithography. The body usually a stout esparto paper; the surface somewhat dull and more absorbent than an art paper. The term is derived from the Greek word meaning colour.

Cigarette.—A specially made tissue, unsized, containing little or no loading material; used as its name implies for cigarettes.

Coated.—A general term applied to art, chromo, enamel and other papers which consist of paper surfaced on one or both sides with an adhesive mixture of a mineral substance and glue.

Coating.—Paper used for manufacture of coated papers. For high-class art, paper is a mixture of esparto and wood pulp; for common box papers, a mixture of chemical and mechanical wood pulps.

Collar.—Paper prepared from cheap wood pulps, surfaced with linen muslin, heavily coated with mineral matter and highly glazed. Used for paper-collars.

Collotype printings.—Thick papers or boards made of rag or a mixture of rag and esparto. Surface generally a little rough. Must be fairly hard sized to resist the damp surface of the jelly used in printing.

Colombier.—A special size for drawing paper, $34\frac{1}{2}$ inches by 24. The term is a French word, meaning pigeon-hole. Frequently termed Columbia. Derivation uncertain.

Copying.—Used for the manufacture of letter-books, for copying. A special tissue paper, thin, strong, unsized, but usually glazed. Buff Japanese paper is specially suited for this purpose.

Cork.—Used for packing glass and fragile goods, consisting of heavy coarse straw paper surfaced with a mixture of glue and powdered cork.

Cotton sampling.—White or coloured wrappers used for displaying or packing cottons and cotton goods. Made from strong fibres, such as jute, soda, wood and rag.

Cover.—Thick heavy rag or wood paper, rough machine-finished and soft sized, used, as the name implies, for covers to pamphlets, catalogues and cheap books. Usually sent out in deep strong artistic colours.

Crayon.—High-class heavy rag papers, tinted or plain coloured, glazed on one side only. Used for crayon drawings, water-coloured, and sepia drawings.

Cream laid.—An ordinary writing paper of creamy colour, made on a "laid" wire mould, or on a machine provided with a "laid" wire dandy-roll. (See *Laid.*)

Crepe.—Very thin, tough, strong paper, made of common rags usually, coloured to fancy, and passed through heavy embossed rollers, which crinkle the paper into a form resembling crape. (French *crêpe.*) Used for fancy and decorative purposes.

Crinkled tissue.—Common tissues, plain or coloured, crinkled by rollers specially embossed.

Crown.—A special size of paper or mill-board measuring usually 20 inches by 15.

Term originally applied to a sheet of this size having a crown as a water-mark.

Cutlery.—Common wood or jute papers, prepared so as to ensure freedom from acid compounds, or substances likely to produce sulphuretted hydrogen. Badly prepared paper causes rust or tarnish.

Cutlery ropes.—A term applied to cutlery papers made from hemp or old rope.

Cyclostyle.—Waxed tissue paper used for cyclostyle work. (See *Stencil.*)

Deckle-edged.—Paper from which the *deckle edges* have not been removed. The curious rough edge is due to the pulp being in contact with the deckle or frame of the mould, and on drying this edge is always rough. The deckle-edge of genuine hand-made paper can be imitated in machine-made paper.

Demy.—A special size of paper, so called from the French word *demi*, meaning one-half. Appears to have been one-half imperial, probably being first known as demi-imperial, and then contracted to demi, and corrupted to demy.

Drab-sealing.—Drab-coloured sealing papers.

Drawing.—Paper of various qualities used by artists and draughtsmen. Best qualities made of linen; kept in stock for a long while before use. Surface and finish varied to suit requirements.

Drying.—Strong tough rag or wood-pulp papers, of medium thickness, used for letterpress copying-books and similar purposes. Unsized and absorbent.

Dry printings.—A term applied to common papers used for news, printed dry from the reels. Most reels were formerly damped on the surface before being put into the Hoe printing presses.

Duplex.—Paper having differently coloured surfaces prepared in various ways. (*a*) on a coating-machine, each side being coated with a coloured mixture; (*b*) by passing simultaneously two wet sheets of paper differently coloured, through heavy couch-rolls at the wet end of a paper-machine. Used for programmes, book covers, advertisements, &c.

Elephant.—High-class drawing paper measuring 28 inches by 33. Name probably due to the use of an elephant as the water-mark, but origin of same uncertain. This size, with slight variations, now used for printings and paper-hangings.

Embossed.—Paper upon which a raised or depressed design has been formed by means of special steel rollers, the surface of which has been cut to a particular pattern.

Emery.—Used for cleaning and brightening iron goods. Prepared by coating a strong paper previously moistened by glue, with fine emery powder, which is sprinkled on by a revolving brush. The better qualities are made with a fabric of dressed cotton cloth in place of paper.

Enamel.—A term applied in various ways to (*a*) cheap highly polished coated papers used for box covers; (*b*) to cards coated with a mixture of zinc white and glue.

End.—(See *Book End.*)

Engine-sized.—Sometimes called E.S. papers, because the sizing is effected by adding the rosin size to the pulp in the beating-engine.

Esparto.—Papers made of esparto *per se*, or mixed with small proportions of wood pulp, specially adapted for magazine and writing papers.

Featherweight.—(*a*) Name applied to very light thick printing papers used for novels; (*b*) Name applied to certain writing papers, thin and opaque, made from soda wood.

Fibre leather.—Boards made of pulped leather clippings with or without an admixture of wood pulp, strong waste papers, &c. Used for boxes and trunks.

Filter.—Special papers used in chemical laboratories for filtration purposes. Made of pure rag, carefully beaten, unsized, free from mineral constituents and fat. Best qualities extracted with hydrochloric and hydrofluoric acids to ensure absolute purity.

Flint.—Papers, usually coated, to which an extra polish has been imparted by friction with a long flat stone moving quickly to and fro across the surface of the paper as it comes through the calenders.

Fly.—Paper coated with molasses, which render it sticky, or impregnated with some chemical such as arsenic, quassia bark, &c., to render it poisonous. Used for killing flies.

Foil.—Paper coated with tin, copper or zinc in the form of metallic powder. Used for decorative or packing purposes.

Foolscap.—A special size of writing paper, measuring $16\frac{1}{2}$ inches by $13\frac{1}{4}$. So called from the water-mark of a fool's cap first used for this size of paper.

Friction glazed.—Paper specially glazed or calendered by a stack of calenders in which some rolls are of small diameter and revolve at a much higher speed than the others, thereby creating friction against the paper.

Fumigating.—Paper soaked in nitrate of potash, dried and then steeped in an alcoholic solution of some fragrant balsam, such as *tolu*, or *storax*.

Glass.—Paper moistened with glue and then sprinkled over the surface with finely powdered glass. Used largely by carpenters and joiners for polishing wood.

Glazed boards.—Box-boards glazed by any process.

Granite.—Mottled papers, in which the appearance of granite is imitated.

Grass-bleached tissue.—Thin tissues of special white colours, used for wrapping stationery goods. Name used to signify a good colour as obtained by the old custom of exposing linen textiles to air and sun on grass for bleaching.

Grease-proof.—A paper of thick or thin substance used as a wrapper, for jam-pot covers, and packing food of a greasy nature. May be a genuine vegetable parchment or merely an imitation.

Grocery.—A general term for all kinds of paper used in the grocery and provision trades.

Gummed.—Ordinary papers coated with common gum, or with dextrine (British gum). Special qualities used for stamps, made of thin esparto paper.

Hand-made.—A general term applied to papers made on hand-moulds, as distinct from machine-made papers.

Hemp.—Papers made from hemp, hemp refuse, old hemp ropes, &c. Used for wrappers, cable and insulating purposes, and sometimes called *Hemp browns*, if used specially for wrappers.

Hosiery.—Papers of all qualities and colours used in the hosiery trade, principally wrappers.

Imitation art.—Prepared by adding large quantities of china-clay to pulp, passing the finished paper through supercalenders, the surface being moistened with water just as the paper enters the calender.

Imitation parchment.—A wood-pulp paper, strong, transparent, fairly grease-proof and waterproof, these special qualities being imparted by prolonged beating and not by chemical treatment.

Imperial.—A special size of drawing or writing paper, usually 30 inches by 22. Term probably originated in its application to a special high-class rag paper suggested by the royal *papyri* of the Egyptians.

Ingrain.—A fancy name for *mottled* papers.

Insides.—Term applied to all the sheets in a packed ream of paper which are good, as distinct from the four or five outside sheets which are generally regarded as damaged

Insulating.—Strong well-sized acid-free papers made from hemp or jute, singly or mixed. Pulp specially washed free from soluble salts in order to render the paper less liable to absorb moisture, and thus maintain its insulating capacity.

Iridescent.—Paper exposed to fumes of ammonia, having been first soaked in a mixture of gum, sulphate of iron, sulphate of indigo, and nut-galls, in solution.

Ivory-finished.—Papers or cards of superior quality highly glazed by rolling or calendering, bees-wax being rubbed on the rolls to obtain the special gloss called *ivory finish.*

Jacquards.—Thick papers of ordinary quality made from jute and waste papers, cut and perforated to suit the Jacquard looms in spinning-factories.

Japanese.—Papers of various qualities and substance, the peculiar strength and appearance being due to the fact that the natives literally beat out the fibres with mallets until isolated sufficiently, retaining their full length. This description only applies to papers made in a primitive fashion by the Japanese.

Kraft browns.—Brown papers made of soda wood pulp of high-class quality, and designated by the German word *kraft*, meaning *strength.*

Laid.—Papers made on a laid mould, or with a laid dandy-roll. A laid paper held up to the light appears to be water-marked by a number of lines *laid* close together, intersected by lines at right angles placed about one inch apart, the effect being due to the formation of the mould or dandy-roll.

Lapping.—A suggestive term applied to various common cartridges, parchments and other wrappers used for packing tea, coffee, dry goods, bottles, &c.

Leather boards.—Imitation leather made by pulping up leather clippings and fibres such as waste papers, jute, &c., and converting same into paper and board. Used for bookbinding and covers.

Ledger.—Strong account-book papers, made from high-class rag, coloured more or less blue, tub-sized and well rolled.

Linen.—Drawing or writing-papers containing no fibrous ingredient except linen rag.

Litmus.—A chemical test paper made by soaking filter paper in tincture of litmus. Dipped into acid solutions the paper turns red; into alkaline solutions it turns blue.

Litho.—Contracted form of *lithographic.* A soft-sized esparto paper, carefully made and dried, so that when moistened during the various printing operations, the expansion or stretch is very slight. Used for illustrations and colour printing.

Loans.—Thin rag papers of great strength, tub-sized, water-marked, and sometimes hand-made. Similar to *banks* in being made from pulp beaten for a long period of eight to ten hours. Difference very slight, a *loan* being usually heavier than a *bank*, and not too highly glazed.

Loft-dried.—A term applied to any papers dried by being hung up in a drying-shed or loft, and finished by a natural process of evaporation of the moisture.

Luminous.—Prepared by mixing glue, bichromate of potash, and phosphorescent powder with pulp, before the paper is made, or by coating finished paper with the mixture.

Machine-finished.—Any papers glazed and calendered by a calender which is placed at the end of a paper-machine, in which the paper passes direct from drying-cylinders to calender.

M.G. Caps.—Machine-glazed caps, or thin wrapping paper made from rag or wood pulp used for bags. Strong, tough paper, glazed on one side only, being made on a single-cylinder or Yankee machine.

Manifold.—A thin copying paper, or a slightly waxed tissue, used for interleaving order-books, letter copying-books, counter invoice forms, &c.

Manila.—A strong paper, supposed to be made entirely of manila hemp. The term now loosely applied to many papers made entirely of chemical wood pulp. Used for bookbinding, tags, musical instruments, &c.

Marble.—Used for covers of school exercise-books and note-books. Prepared by floating common thin papers on a bath of gum tragacanth, the surface of which has been sprinkled with various colours, and combed out to a desired pattern. Cheaper qualities prepared by colours sprinkled by revolving brushes on the sheet of paper as it travels continuously forward.

Medium.—Name applied to a size of paper usually 22 inches by 17½. Origin of term uncertain, but possibly arising from the use of a paper having a size intermediate between two other sizes, such as foolscap, 17 inches by 13½, and imperial, 30 inches by 22.

Metallic.—Used for note-books, steam-engine indicator diagrams, &c. Prepared by coating paper with a mixture of whiting, lime and zinc white, the surface being afterwards glazed.

Middles.—Name given to common cardboard prepared from waste papers or mechanical wood pulp. Used for tram tickets and as a cheap basis for surfaced cards, produced by pasting paper of good quality on this cheap cardboard. Hence the suggestive name.

Millboard.—Boards made of wood pulp, waste papers, and all kinds of fibre refuse. Usually well rolled or milled.

Mother-of-pearl.—Obtained by immersing glazed paper in a bath of silver or lead salts, allowing it to dry, exposing to the vapour of sulphuretted hydrogen gas, the iridescent effects being then fixed with collodion.

Mottled.—Paper having a variegated coloured surface, produced by mixing a *small* proportion of coloured fibre with pulp which has been dyed to a different shade, so that the paper appears to contain a number of fibres floating on the surface, having a colour distinct from that of the main body of the paper. (See *Silurian.*)

Mould-made.—Imitation hand-made paper, sometimes made on a cylinder mould, the surface of which is divided into sections by thin rubber strips fastened on, thereby producing false deckle edges; sometimes on large flat mould subdivided in a similar manner by rubber strips or copper wire.

Music.—A thick, soft opaque printing paper, made of esparto, sometimes with a small proportion of wood pulp. Not hard-sized and only slightly calendered. Used as name implies.

Nature browns.—Brown wrappers made of boiled mechanical wood pulp, jute, or unbleached chemical wood pulp, the colour of the paper being derived from that of the pulp itself, without modification by dyes.

Needle.—(See *Cutlery.*)

News.—Common machine-finished, soft-sized printings, made from mechanical and chemical wood pulps, and containing usually 70 per cent. of mechanical.

Ochre-glazed.—Wrappers of various qualities coloured with sundry ochres, which produce a warm burnt-sienna shade, and glazed.

Oiled.—Used for letter copy-books. Prepared by soaking ordinary paper in linseed oil, or a mixture of spirit and linseed oil.

Outsides.—The few extra sheets forming the outside of a ream, and generally regarded as damaged. Also applied to specky, poorly made sheets of hand-made paper, put up and sold apart from good sheets.

Oxford Bible.—A special rag paper, strong, opaque, and thin, prepared by careful beating of selected rag.

Pamphlet.—A medium quality of printing paper used as name implies.

Panel boards.—(See *Carriage panels.*)

Parchment.—The skin of goats, sheep and other animals, cleaned and dressed for writing. Now used for important legal documents only. The term is now also applied to well-beaten rag and wood pulp papers of good quality.

Papier-mâché.—Waste papers pulped, mixed with mineral matter, such as china-clay, rosin, &c., and afterwards moulded into a variety of goods by steel dies, the manufactured articles being chiefly for domestic use.

Pasteboard.—Common boards made by covering middles with pastings.

Pastings.—Common white or coloured printings, used for lining boxes, boards, middles, &c., glazing frequently done when the paper has been mounted on the board. Also applied to good papers pasted on to high-class cards.

Photographic.—Paper prepared specially with pulp from which all chemicals have been carefully removed. Contact with iron during manufacture avoided as far as possible.

Pin.—Paper used for packing pins; qualities according to price.

Pinched post.—A smaller size of post paper, the word "pinched" being an expressive term.

Plate.—Rag paper of good quality, sometimes made of several thicknesses of unsized paper caused to adhere by great pressure when moist. Slightly tub-sized and sometimes calendered on one side only. Used for steel-plate engravings, from which the name is derived.

Plate-glazed.—Paper glazed by being placed between zinc or copper plates, which are then passed through steel rollers under great pressure.

Portmanteau boards.—Hard strong boards made of waste paper, containing sometimes leather waste; used as name implies.

Post.—Name given to a particular size of writing paper, measuring 19 inches by $15\frac{1}{4}$. Originally applied to this size because the water-mark was a postman's horn.

Posters.—Common printing paper, used for the production of advertisements for bill-posting and outdoor display. Best qualities strong and well sized.

Pott.—Name given to a certain size of writing paper 15 inches by $12\frac{1}{2}$, originally made by hand and recognised by the watermark, a tankard or pot.

Pottery tissue.—(*a*) Thin tissues of good quality, well glazed, used for wrapping pottery ware; (*b*) special tissues by which designs are transferred to pottery.

Pressings.—Common papers used for pamphlet and copy-book covers.

Printings.—A general term for paper used by printers. Qualities innumerable, and composition varied. Chiefly esparto, chemical and mechanical wood-pulp, with or without loading.

Programme.—Paper made from esparto, sometimes containing a proportion of wood, made specially soft so that the printed sheets do not rustle when handled. The softness often produced by a large excess of clay put into the paper.

Rag.—Paper made from rags.

Railway buff.—Common printings used for railway advice sheets and circulars; yellow or buff-coloured.

Retree.—Imperfect or damaged paper, often put up and sold at reduced price. Name corrupted from French word *retirer*, to withdraw.

Repped.—Paper passed through steel rollers which produce a raised or ribbed surface. Used for fancy purposes. The word is an adaptation of "ribbed."

Roofing.—(See *Tar paper.*)

Rope browns.—Brown papers made from old ropes, a term frequently used to infer extra good quality, though ropes often contain inferior fibres.

Royal.—A particular size of paper which varies according to quality. For drawing paper 19 inches by 24, for printings 25 inches by 20. Name originally applied to a certain size distinguished by a water-mark of the royal crest of France, a fleur-de-lys.

Royal hands.—Term applied to certain packing papers measuring 25 inches by 20, made from wood pulp and other material. Originally used for drawing paper of high quality and applied to packing paper on account of similarity in size. Term first used by reason of the "royal hand" water-mark.

Saddleback.—A wrapping paper 45 inches by 36, used in cotton mills for packing cotton goods. Name probably due to size being suitable for yarns taken off from part of the machine called a saddle.

Safety.—Paper used for cheques, coupons, and similar purposes. Generally the colour is very sensitive to acids and alkalies. The pulp is impregnated with salts, such as iodides of bismuth, coal-tar dyes, manganese sulphate.

Sampling.—White or coloured paper specially made, fairly heavy and thick, used for display of textiles and similar samples.

Sand.—Heavy papers covered with fine sand, fixed to the surface with glue. Used by carpenters and joiners.

Sealing.—Wrappers of various qualities used by stationers in packing stationery. Name probably due to the custom of first using a definite quality and size, the fastening of the packets being effected with sealing-wax.

Self blues.—Papers made from pulp coloured by the addition of blue rag pulp. The colour is specially fast to light, being derived from indigo-dyed rags.

Self-coloured.—A term employed to indicate that no colouring-matter has been added to the pulp from which the paper was made.

Silver tissue.—Tissues used for wrapping silver, made of rag or wood pulp. Paper free from acid, and any substances akin to sulphur, which causes silver to go black. Papers of this class can be dipped in an alkaline solution of zinc oxide.

Silurian.—A mottled paper of a characteristic greyish colour variegated by fibres of a deeper bluish grey shade which are distributed through the sheet. Used for fancy stationery; name probably due to its resemblance to certain kinds of stone.

Shop papers.—A general term for thin wrappers.

Skips.—Thin brown paper used for lining crates in which cotton goods are packed. "Skip," a north country word for crate, or packing-case.

Slate.—Thin paper or cardboard coated with a black composition, used as a substitute for slates in schools.

Small hands.—Packing paper of a definite size made of wood pulp chiefly, formerly of common rags, name probably derived from size being once used for a writing paper distinguished by the water-mark of a *hand*.

Starch.—(*a*) White or blue papers used for drying and packing starch. (*b*) Chemical starch test-papers.

Stencil.—Used for cyclostyles and other manifolding machines. Made by impregnating strong tissue paper with paraffin wax.

Stereo-tissue.—An extra strong pliable tissue made from rag or wood pulp used in the production of stereos for newspaper printing. The tissue, backed by a common blotting and a common brown, is placed on the type and formed into a mould for further use.

Straw boards.—Box and packing boards made of straw pulp which has received very little chemical treatment.

Sulphite browns.—Brown wrappers made from sulphite wood pulp.

Supercalendered.—Paper, printings, and writings, which have been glazed in the supercalender.

Superfine.—A term denoting extra good quality. (Latin *Super* = above.)

Superglazed.—A paper with extra finish.

Super-royal.—A particular size of paper 20 inches by 28. Larger than royal.

Surface-coloured.—Papers coloured on surface only, by an ordinary coating-machine, or by means of chased brass rollers.

T.S.—A contracted term meaning tub-sized papers, to denote paper sized with gelatine. Hand-made papers are sized by being dipped into a vat or *tub* of animal size.

Tape.—Paper made from esparto and rag, used for Morse telegraphs and similar machines. Made specially regular as to thickness and substance.

Tar.—A coarse paper impregnated, or sometimes merely coated, with thin tar. Used for roofing or packing, being waterproof.

Tartan.—Strong variegated coloured cartridge papers used for book covers, made from rag and wood pulp.

Tea.—Various kinds of paper used for packing tea, generally coated on one side with tinfoil.

Tinfoil.—Paper coated with tinfoil, the latter being tin in a finely divided state produced by chemical precipitation, which is pasted on the surface of the paper.

Tips.—White or coloured common papers used for the manufacture of spools for cotton.

Tobacco.—Wrapping paper for tobacco, usually common paper enamelled and highly glazed.

Toned printings.—Common printings coloured with iron or aniline dyes to a well-known stone grey or buff colour.

Tracing.—Paper rendered transparent for tracing purposes by being soaked in a solution containing a mixture of Canada balsam, turpentine, and a trace of vegetable oil, and then hung up until dry.

Transfer.—Paper used for the transfer of coloured pictures and designs to tin vessels and boxes used for packing food and condiments. The paper is first surfaced with starch and then coated with gum, or dextrine.

Transparent.—(See *Tracing.*)

Triplex.—(*a*) Paper surfaced with three colours used for tickets and wrappers; (*b*) term applied to stiff paper composed of a *middle* surfaced on either side with coloured papers.

Turmeric.—A chemical test-paper prepared by soaking filter-paper in an extract of turmeric root. Used for detecting traces of alkali.

Typewriting.—Special thin writing papers of rag or wood pulp used for manifold copying by means of the typewriter.

Vat.—Hand-made papers, so called because the mould is dipped into the vat containing the pulp.

Vegetable parchment.—Paper rendered waterproof and greaseproof and partially transparent by having been dipped into a mixture of sulphuric acid and water for a few seconds, and immediately washed in fresh water, traces of acid being finally neutralised with weak alkali. Used for jam-pot covers, &c.

Vellum.—A thick writing paper somewhat resembling vellum or prepared calfskin in appearance, made from high-class rags which have been subjected to long beating.

Veneer.—Thin pulp or fibre boards suitably coloured and highly glazed; used as the name implies.

Vulcanised.—Paper or boards treated superficially with a strong solution of zinc chloride, and thereby rendered very hard and waterproof. Sheets pressed together when wet form a compact mass.

Water-finished.—Paper highly glazed by the action of the supercalender on the surface of the paper, which has been moistened just before entering the rolls of the calender.

Waterleaf.—The term applied to sheets of hand-made paper or machine-made paper before being sized, or which are not sized.

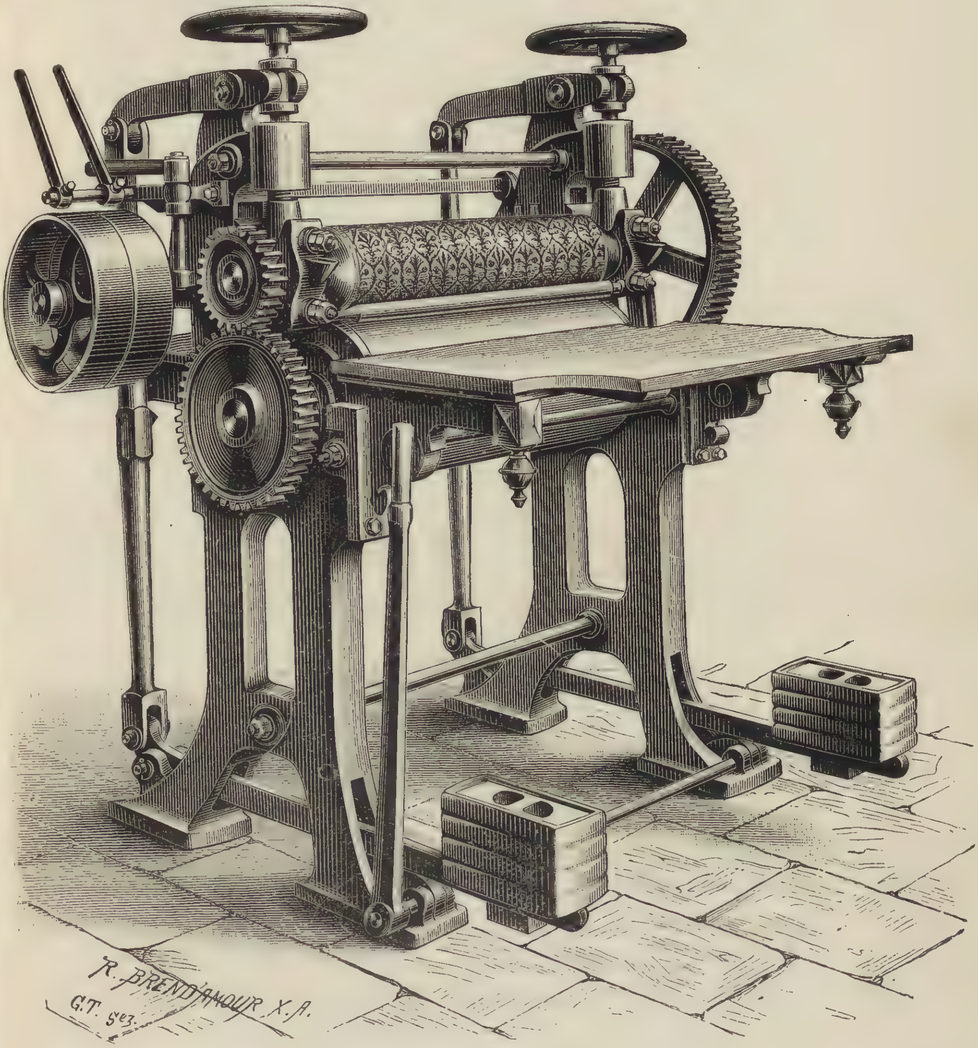


Fig. 158.—Embossing Machine.

Water-marked.—Any paper containing a water-mark, or distinct design produced by the raised pattern on a mould or a dandy-roll.

Waterproof.—Various sorts: (*a*) Roofing and tar papers; (*b*) imitation parchments and greaseproofs; (*c*) oiled papers; (*d*) special qualities prepared by soaking paper in a solution of shellac, with or without borax.

Waxed tissues.—Tissues impregnated with paraffin wax. Used for stencils, cyclostyle work, confectionery.

Whatman's.—A celebrated high-class drawing paper named after the original maker, one of the earlier pioneers of paper-making.

Willesden.—Paper impregnated or surfaced with an ammoniacal solution of cupric oxide, which acts upon the fibre, renders it partly gelatinous, and imparts the quality of imperviousness to water. Used for roofing, &c.

Wood browns.—Brown papers made from sulphate and soda pulps under various special names.

Wood pulp.—A general term for paper made from wood pulp. Qualities numerous.

Wood-pulp boards.—Thick stiff paper made from wood pulp, and designated *boards*, as being an efficient substitute for box-making purposes and book covers.

Wove.—A term applied to paper made on a woven wire, in which the wires cross and recross at even distances apart in a manner quite distinct from *laid* wires.

CHAPTER XIX

QUESTIONS ON "PAPER MANUFACTURE" SET BY THE CITY AND GUILDS OF LONDON INSTITUTE

1902.

Ordinary Grade.

1. In boiling rags with caustic soda, what are the principles which regulate the conditions of treatment, viz., chiefly : proportion of soda and of total liquor to rags, temperature and time of boiling ? What information as to progress of the treatment is furnished by analysis of liquor ? (30 *marks.*)

2. What are the characteristics most desirable in papers for (1) photographic mounts, (2) typewriting, (3) ledgers, (4) school books (illustrated in colours) ? Give the furnish you consider most suitable, and state the precautions you would adopt to secure the best results. (25.)

3. What instruments are used in the mill to measure (1) temperature, (2) proportion of moisture in the air, (3) specific gravity, (4) weight and thickness of papers ? State briefly what you know of the uses of such measurements. (30.)

4. Give a concise description of (1) Lowden's steam regulator, (2) the Marshall train ; and discuss the advantages claimed in each case. (25.)

5. In boiling Spanish esparto, how much caustic soda would you use per ton of grass, and at what dilution ? State the latter as percentage (NaOH) on the liquor, and from this the (approximate) number of gallons per ton. At the conclusion of the boiling, how would you estimate the addition to volume of liquor due to condensation of steam ? (20.)

6. What style of damper do you consider most suitable for damping (1) supercalendered printings, (2) imitation parchments, (3) glazed casings, (4) soft-sized friction-glazed printings ? Give practical details to be observed in damping each of the papers named. (20.)

7. State what you know of the composition of bleaching-powder and the bleaching action of the hypochlorites. How would you carry out the bleaching of half-stuff so as to provide for an intermediate washing of the pulp ? What are the advantages of so doing ? (25.)

8. State fully the treatment you would adopt to impart to a strong book paper the characteristics of a hand-made sheet. Give furnish you would use, with proportions of boiling and bleaching liquors ; the duration of treatment in each department, and reasons for the adoption of any special appliances. (30.)

9. What compounds of cellulose are soluble in water, and how are they prepared ? Which of these are used in paper-making, and what are the special effects they produce ? (25.)

10. Describe Cornett's system of handling and treating esparto, and discuss its merits compared with any other system you are acquainted with. (25.)

11. What materials are used (*a*) for weighting or loading papers in the engine, (*b*) for surfacing or coating, (*c*) for colouring (in the beater) red, blue, yellow and black ? Mention one pigment and one soluble dye in each case. (25.)

12. What precautions would you take to prevent froth and air bubbles when making thin printings at a fast speed, with a furnish of 30 per cent. broke and 70 per cent. esparto? (20.)

Honours Grade.

1. Permanganate of potassium is used as a bleaching agent in neutral solution. How does it break up, and what further treatment of a pulp would be required to eliminate the products of decomposition? Compare approximately the cost of this bleach at £50 per ton for $KMnO_4$ with that by bleaching-powder of 35·5 per cent. "available Cl" at £6 10s. a ton. (25 *marks.*)

2. Which variety of wood fibre do you consider most suited to blend with (1) linen rags for typewriting papers, (2) esparto for fine printings, (3) soft cottons for blottings, (4) manila ropes for cartridge papers? State the treatment you would adopt for the preparation of the various wood pulps from the raw materials, and give data for boiling, washing and bleaching, also composition of boiling and bleaching liquors, with the yield of pulp you would expect from 10 tons of raw wood. (30.)

3. Discuss fully the question of economy in boiling rags with caustic soda. By what chemical tests would you control the operation and fix the best conditions in particular cases? (25.)

4. State your opinion regarding the use of exhaust steam from the machine engine for heating the drying-cylinders, and compare the method with that of employing a condensing-engine and drying with high-pressure steam. Show how you arrive at the steam consumption for each method. (30.)

5. What are the average limits of thickness of writing papers? For a given mean thickness, calculate the weight per square metre of paper of 50 per cent. "cellulose density" (*i.e.*, equal volumes fibre substance and air-space). Taking a breaking length of 7500 metres, what maximum weight will the paper support per 1 centimetre of breadth? Take the specific gravity of cellulose at 1·5. (25.)

6. Describe the plant you would put down to recover and causticise the soda in the liquors from the boiling and the washing of 100 tons of esparto per week. State the approximate number of gallons per boiler, the percentage of soda you would expect to recover, and the cost for labour, lime and coal per ton of soda recovered. (25.)

7. Discuss fully the conditions of penetration of papers by size solutions in tub-sizing. How would you vary these conditions, including the composition of the size, to produce the best effects? How would you investigate the paper to ascertain the distribution of the size and the sizing effect? (20.)

8. State fully how you would handle the beating tackle when beating the pulp for the papers mentioned in Question 2. What special methods would you adopt to secure that the wood fibres would be so blended as to prevent the finished sheet from having a "woody" appearance? (20.)

9. State what you know of the hydrated modifications of cellulose, and their functions in the paper-making process. What special effects are obtained by these hydrates chemically prepared? (25.)

10. Wherein lie the advantages of the multiple-effect evaporator and the rotary furnace? State what you know of the practical working of each, and compare them with the Porion system as to the efficiency and cost of maintenance. (20.)

11. Give briefly a full scheme for the analysis and testing of writing and book papers. Give also a selection of these tests for rapidly determining the main features of composition. (25.)

12. Schedule the proportions of chemicals you would use in boiling and

bleaching (1) manila ropes for strong cartridges, (2) flax waste for caps, (3) unbleached cottons for loan papers, (4) jute for casings, (5) muslins for blottings. State temperature, pressure and duration of boiling, together with any special modifications you consider advantageous. (30.)

1903.

ORDINARY GRADE.

1. Describe the structural features of straw and esparto and of the fibres of their respective half-stuffs. What are the average dimensions and structural features of cotton and linen (flax) when fully beaten? (25 *marks*.)

2. What advantages are gained by using bronze instead of steel for beater bars and plates? State the materials in the preparation of which you would expect to secure the best results from the use of bronze. (20.)

3. Mention the various forms of wood pulps with their more particular uses. Give a short account of their preparation from the original woods. What do you understand by a "strong sulphite pulp," and how would you determine whether a given sample conforms with this description? (25.)

4. Describe the conditions which give rise to "blowing" in front of the first press-rolls, and state the precautions you would take to prevent it when making thin paper on a close texture of wet felt. (20.)

5. With bleaching powder of 35·5 per cent. "available chlorine" at £4 15*s*. a ton, calculate the value of the "chlorine" per pound and per kilo. A waste bleach liquor is tested and found to contain 0·01 gramme "chlorine" per 100 cubic centimetres; what quantity does this represent on 963 gallons of the liquor? Calculate the quantity of sulphite antichlor—$Na_2SO_37H_2O$—required to neutralise. (25.)

6. What advantages, if any, are obtained by running esparto over the presse-pâte previously to bleaching. (25.)

7. What do you understand by (*a*) a neutral, and (*b*) an acid rosin size? Give working particulars for preparing and using them. What is an average dilution of the rosin size in the beater, and how is rosin compound affected by the dilution. (30.)

8. Which type of refining-engine would you put down to supplement the beating power for the preparation of stock for (1) esparto printings, (2) news 3) typewriting papers, (4) glazed casings? Give your reasons for the adoption of any particular type, and state what increase in the production you would expect to obtain. (30.)

9. A water is found to contain:

	Grains per gallon.
Lime	11·2
Magnesia	8·0
Sulphuric anhydride	8·0
Carbonic anhydride (expelled on boiling)	13·2

Express these results as "parts per 100,000," and give the chemical formulæ for the constituents. What chemicals would be required to soften this water? (20.)

10. Give a brief description of Bertram's vacuum ejector, and discuss its merits compared with the ordinary vacuum pumps for extracting the water from the paper in its passage over the wire. What saving in power would you expect to obtain when using the ejector? (25.)

11. Give a brief account of the substances represented by the following formulæ, and describe their ordinary commercial forms: NaOH, Na_2CO_3,

$NaHCO_3$, CaO, $CaSO_4$, Ca $(OCl)_2$, $Al_2(SO_4)_3$. State what you know of the composition of ultramarine, smalts and china-clay, casein and gelatine. (30.)

12. State the practical details you would observe when making a thick chromo paper, so as to ensure freedom from stretch and dust in printing. (25.)

Honours Grade.

1. With Spanish esparto at £4 15*s.* a ton f.o.r., trace the increments of cost of the cellulose through the several stages of preparation up to the stuff-chest. (25 *marks.*)

2. Draw up a scheme for the production of the following papers, showing the proportions of the various materials you would use, and their approximate cost per ton of finished paper: (1) Fine writings at 5*d.* per pound, (2) E.S. printings at $2\frac{1}{2}d.$ per pound, (3) news at $1\frac{1}{4}d.$ per pound, (4) M.G. caps at $1\frac{1}{4}d.$ per pound. State the average cost of production in each case. (30.)

3. Write a short general account of rosin sizing, dealing particularly with the following points: (*a*) proportion soda to rosin, (*b*) effect of dilution before adding to the beater and in the beater, (*c*) hard and soft waters and use of back water in the beater, (*d*) auxiliary action of colloidal alumina, starch and cellulose, (*e*) thin and thick papers, (*f*) "wet" and "free" running on the machine. (25.)

4. State your ideas as to the future of electricity as a motive power in the paper-mill, and describe what you know of its application at the present time. (25.)

5. What tests can be applied to stuff in the beater to follow the progress of the beating? Sketch a plan of systematic records in regard to the preparation of the stuff. How can the beating be influenced by chemical means? (25.)

6. How would you proceed to produce a "feather-weight" printing at $2\frac{1}{2}d.$ per pound? Schedule the materials you would use and the practical details you would observe in the manufacture in order to impart the desired characteristics to the finished sheet. (25.)

7. Give a general account of hard and soft waters in relation to (*a*) steam-raising, (*b*) the paper-making processes. A water contains per 100,000 parts:

$CaCO_3$ (as bicarbonate)	18·5
$MgSO_4$	9·4

Calculate the chemicals required to soften per 1000 gallons, and show the advantages of using the softened water in the case of an esparto mill. (30.)

8. What do you know of the requirements of an "imitation art"? Give an approximate furnish for this grade of paper at $2\frac{3}{4}d.$ per pound, and state how you would treat it in the various processes from the wet end to the cutter in order to get the best results. (20.)

9. Criticise the expression "breaking length" of papers, and show where it fails as a comparison of actual breaking strains. What do you propose in its place? Propose such tests of "opacity" and "surface" or finish as admit of numerical records. (25.)

10. Describe how you would proceed to convert ten tons of jute bagging into a strong cartridge paper, and schedule the duration of each stage, with the percentage of chemicals, steam pressure and temperature of bleaching solution. State how you would prevent chlorination of the fibres, when obtaining as white a colour as possible, consistent with retaining the strength and the yield of finished paper you would expect to obtain. (25.)

11. Give a classification of raw fibrous materials and commercial half-stuffs (1) according to chemical characteristics, (2) according to the main types of paper which they are used to produce. (25.)

12. Whether do you consider it to be more economical to supplement the steam-raising plant by installing a forced-draft apparatus with mechanical stoking, or by adding an additional boiler and firing by hand? State which type of forced draft and mechanical stoker you consider most efficient. (25.)

1904.

Ordinary Grade.

1. What is the volume of a ton of water? Give an approximate estimate of the dimensions of a reel of newspaper weighing 250 kilos. What is the thickness of a cigarette paper, and the approximate weight per square metre? (25 *marks.*)

2. What dyes would you use for the production of the following papers: Geranium red, canary yellow, fast blue? State the precautions you would adopt to produce the best results, most economically, in each case. (25.)

3. Specify furnish for (*a*) best white blottings, (*b*) biscuit caps, (*c*) cutlery wrapping. Contrast the details of preparation of the stuff in relation to the particular qualities. (25.)

4. State the materials you consider most suitable for the production of a buff copying, and give a brief outline as to how you would treat them so as to give the desired characteristics to the finished sheet. (25.)

5. Write a short account of the water-soluble compounds of cellulose. (25.)

6. How would you manipulate the various parts of the paper-making machine in order to produce a fine printing, the under side of which would be, as nearly as possible, as smooth as the top side? (20.)

7. Specify composition of normal papers (*a*) for documents of permanent value, (*b*) for book papers. Explain the defects in chemical composition to be avoided. (25.)

8. State the characteristics most desirable in a "body" paper for surface enamelling. Give the proportions of the materials you would use, and state how you would handle the beating-tackle. (30.)

9. Give practical details for making, storing, distributing, and using bleach liquor in the mill. State what you know of the chemistry of bleaching-powder, and the bleaching action of its solution. (25.)

10. Describe briefly Marshall's patent drive for the paper-making machine, and state the advantages you consider to be gained by its adoption. (20.)

11. What are the special chemical and physical features of (*a*) chemical filter papers, (*b*) blottings, (*c*) greaseproof, (*d*) paper for protecting photographic films and plates, (*e*) papers for wrapping cutlery and plate, (*f*) cable papers? How would you test each in regard to special use? (25.)

12. What advantages are to be gained by covering steam pipes with non-conducting material? Give an estimate of the saving which may be effected in a modern machine mill in which a complete system of covering is adopted. (30.)

Honours Grade.

1. Examine critically the efficiency of a beating-engine, both as to economy of power and control of the range of effects required in the preparation of an esparto furnish. (30 *marks.*)

2. Discuss the question of rope *versus* belt driving for the paper-mill machinery. (20.)

3. How would you investigate the effects of calendering upon the physical properties of papers? Show in what respects the ordinary methods of paper-testing fail to exhaust the problems involved. (25.)

4. How would you proceed to insure accurate register if, on starting to make an E.S. writing, the distance between the water-marks was an eighth of an inch too small. (20.)

5. What are the limitations of wood pulp (cellulose) in regard to paper-making effects? How far is this due to structural and chemical features of the cellulose, and how far to deficiencies in treatment in the mill? (25.)

6. What plan would you adopt to guard against excess of soda when supplementing causticised soda liquor with 77 per cent. alkali in boiling esparto. (25.)

7. In colouring or dyeing papers in the engine, what causes affect the permanence of the effect? How would you examine dyed papers in regard to the quality of fastness? Specify for a fast medium blue, red, yellow, and brown on pure cellulose papers. (25.)

8. State your opinion regarding the adoption of gas for motive power in the paper-mill, and describe any gas-producing system with which you are acquainted. (25.)

9. What are the main causes of the deterioration of book papers? Give a chemical account of the effects referred to, and their specific causes. (25.)

10. What are the special requirements most desirable in a paper for photographic prints? Draw up a scheme for the production of such a paper to sell at 6*d.* per lb., stating the materials you would use and the precautions you would adopt to ensure the best results. (30.)

11. State what happens when a drop of iron gallo-tannic ink diffuses into a blotting paper. What use would you make of your observations in comparing the qualities of blottings and controlling the processes of manufacture. (25.)

12. How would you manipulate the various parts of the machine when making "news" at a high speed, so as to produce large equal-bulking reels, free from breaks? (25.)

1905.

Ordinary Grade.

Not more than eight questions should be attempted.

1. Mention three systems of making straw into half-stuff. Give a brief outline of the processes. (20 *marks.*)

2. Describe briefly the action of a Kollergang, and discuss the limits of its usefulness as a substitute for the beating-engine when worked in conjunction with a refining-engine. (30.)

3. The following data are obtained in testing a paper: Weight per square metre, 34·2 grm.; thickness, 0·07 millimetre; breaking length, machine direction, 5473 metres; cross direction, 3724 metres. Calculate specific gravity and mean breaking strain per square millimetre section. (30.)

4. Discuss the relative merits of paper, cotton, and woollen paper for covering calender-bowls. (20.)

5. What is the influence of iron oxide on the durability of paper? How would you show its presence, and how would you trace the source or sources from which it is derived? (20.)

6. What advantages are to be gained by the use of rubber-covered bottom press-rolls? (20.)

7. Trace the relations in the quantity of water to (per 100 kilos.) bleached esparto pulp (calculated as "*dry*") from the time it enters the beater until it reaches (as paper) the last of the drying-cylinders of the machine. (30.)

8. State the precautions you would adopt to prevent frothing when working a large proportion of an aniline dye, such as cotton scarlet. How would you ensure complete exhaustion, and a clean back water? (25.)

9. What cellulose would you select for making papers with regard to the following particular characters respectively: Strength, bulk, opacity, transparency, purity? Can any of these qualities be varied by chemical treatment? If so, how? (25.)

10. Describe the type of strainer you consider the most suitable for the production of (1) rag papers, (2) esparto papers, (3) wood-pulp papers. (25.)

11. What is a thermometer, hydrometer, hygrometer? What are the practical uses of these instruments in a mill? (25.)

12. What saving in coal would you expect to result from feed water at 180° Fahr., as compared with 60° Fahr., the increased temperature being obtained from the use of the waste steam from the machine cylinders? (30.)

Honours Grade.

Not more than eight questions, or five questions and one essay, to be attempted.

1. How would you proceed to investigate the ratio of sizing effect to quantity of sizing agent used in the case of (*a*) engine-sizing (rosin), (*b*) tub-sizing (gelatine)? (25 *marks.*)

2. Describe Masson's patent bleaching tower, and discuss its merits as fully as you can. (20.)

3 Give working particulars, with quantitative details, of three methods of preparing half-stuff from straw. Show how you would estimate the costs of the half-stuffs in each case. (25.)

4. Discuss the relative merits of Spanish and African esparto, and state fully the percentage of chemicals and the duration of treatment necessary to produce a well-boiled pulp of a good colour in each case. (30.)

5. How would you make a paper to contain (*a*) 1 gramme of calcium carbonate per square metre (surface measure), (*b*) per 100 cubic centimetres (volume measure)? How much paper in each case would be required to neutralise 17 cubic centimetres normal HCl? (25.)

6. Describe any one of the various forms of kneaders you are acquainted with, and discuss the limits of its usefulness in the treatment of paper stock. (25.)

7. Describe three methods of estimating mechanical wood pulp in papers. (25.)

8. Describe Parson's steam turbine, and give an outline of its possibilities as a motive power in the paper-mill. (30.)

9. From what you know of the ultimate structure of esparto cellulose, calculate the average number of fibres per 1 cubic centimetre of a printing paper, containing, in addition, 22 per cent. of china-clay (specific gravity 2·83). (25.)

10. State what, in your opinion, are the most important developments in paper-making machinery during the past year. (25.)

11. How would you investigate coloured papers (*a*) for resistance to light, (*b*) for the specific or direct causes of fading? In matching papers, how would you make observations by transmitted light, and what value do you attach to these in matching shades? (25.)

12. What are the characteristics most desirable in a paper for cable insulation? Draw up a scheme for the production of such a paper, and schedule the duration of the various processes you would employ, with the proportions of chemicals necessary. (25.)

As an alternative to questions 3, 7, 11, the student may write an essay on Subject A below; or as an alternative to Questions 8, 10, 12, the candidate may write an essay on Subject B below.

Subject A.—" The general chemical characteristics of cellulose are those of a 'Colloidal Salt.' " Examine this statement critically, both from the standpoint of theory, and of the functions and industrial uses of cellulose. (75 *marks.*)

Subject B.—Discuss exhaustively the question of Beating, dealing with the several types of beaters, their mechanical work, in relation to economy of power, and the incidental chemical effects produced in the beater. (80 *marks.*)

1906.

Ordinary Grade.

1. What effects would you expect to produce on rag fibres by beating with phosphor bronze bars and plates? (20 *marks.*)

2. Briefly describe the following:—Viscose, artificial silk, gun cotton, collodion, vegetable parchment, grease proof paper, vulcanised fibre, celluloid, Willesden paper and silvalin. (30.)

3. Specify the materials most suitable for the production of cutlery wrapping papers, and state the precautions you would adopt to ensure freedom from rusting. (25.)

4. Describe the structural features and give sketches of the microscopical characteristics of the following fibres:—Linen, adansonia, straw, esparto, and cellulose made from pine, birch, and poplar. (25.)

5. Discuss the value of poplar wood pulp as a paper making material, and state the proportion you consider suitable for blending with esparto for the production of a fine printing paper. (25.)

6. Describe briefly, and in the order in which they are carried out, the various processes employed in the manufacture of an engine-sized and friction-calendered paper from cotton rags and chemical wood. (25.)

7. Draw up a scheme for the production of 50 tons "railway" buff per week, and state the characteristics most desirable in such a paper and the precautions you would adopt to insure them. (30.)

8. What colours would you recommend for the dyeing of a cheap dark navy blue, a heavy black, a buff fast to light, and a brilliant crimson on paper pulp? (25.)

9. What advantages are obtained by driving the paper making machine by means of a high-speed enclosed steam engine? (20.)

10. The following results were obtained on testing a paper:—Mean tearing strain, machine way, 11·54 kilos.; cross way, 7·35 kilos.; mean elongation, machine way, 2·8 per cent.; cross way, 5·4 per cent. Weight of strip (0·18 metre by 15 millimetre), machine way, 0·2684 gramme; cross way, 0·2639 gramme. Thickness, 0·153 millimetre. Calculate the mean tearing length in metres and in kilometres; the mean elongation in millimetres; the weight per square metre; the weight (in kilos.) of a sheet of paper, $16\frac{1}{2}$ ins., by $13\frac{1}{4}$ ins. (1-in. = 2·54 cm.); the thickness of a ream (480 sheets) of paper, in centimetres and in inches. (30.)

11. Discuss the relative merits of gas and steam engines for paper mill work. (25).

12. What tests would you apply so as to ascertain whether a paper contains the following substances:—Starch, rosin, gelatin, viscose, casein, and free acid? (20.)

Honours Grade.

Candidates for Honours must hold a Certificate in the Ordinary Grade.

1. State the materials you would use for the production of a high-class Bible paper, and how would you insure opacity and good printing properties? (25 *marks.*)

2. How would you proceed in examining a new, highly lignified, fibrous raw material in order to ascertain its value as a paper making raw material? How would you determine the paper making qualities of the fibres? (25.)

3. What horse-power would be necessary to beat one ton of each of the following materials:—Linen rags for book papers, jute for caps, esparto for printing, sulphite wood for strong casings, and sulphite and mechanical wood for "news"? (20.)

4. Discuss the effect of the following bleaching agents with regard to (1) economy and efficiency; (2) effect on the fibres; (3) influence on the sizing; and (4) effect on the finished paper:—Bleaching-powder, sodium hypochlorite made from bleaching-powder, and bleaching-liquor prepared by electrolysing a solution of common salt. (30.)

5. What conditions are most favourable for the production of "Kraft" papers. Compare the Swedish and English methods, and state what you consider the determining factors in the production of the best qualities of "Kraft." (30.)

6. Describe the various methods of manufacturing "imitation hand-made" papers. How would you distinguish such papers from hand-made? (20.)

7. Specify the materials most suitable for fine boards for picture post cards, and state what instructions you would give to the beater-man to ensure a firm board with a good printing surface. (20.)

8. Describe the different methods of dyeing paper jet black, grey, lemon-yellow, brilliant yellowish green, heavy reddish brown and pale light blue. What reactions would you apply in order to detect in the finished paper the dye-stuffs which you recommend? (30.)

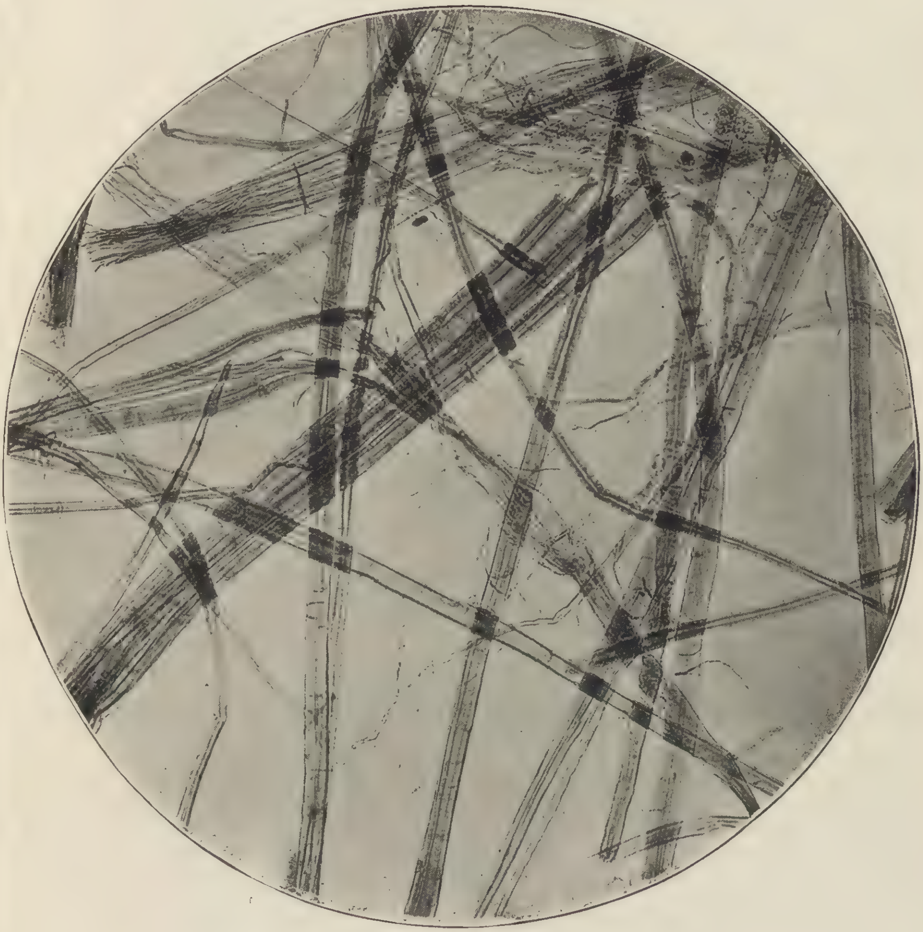
9. Discuss the relative merits of steam, gas and electricity for driving a beating plant to produce 100 tons of wood pulp papers per week. (25.)

10. What is multiple effect evaporation? Describe a complete modern plant for the recovery of soda from boiling liquors. (25.)

11. What precautions are necessary to prevent breaking when making E. S. wove papers from fine cotton and esparto fibres? (25.)

12. Discuss critically the various methods which have been suggested for ascertaining the quantity of mechanical wood pulp in paper. (25.)

MECHANICAL WOOD PULP FROM PINE



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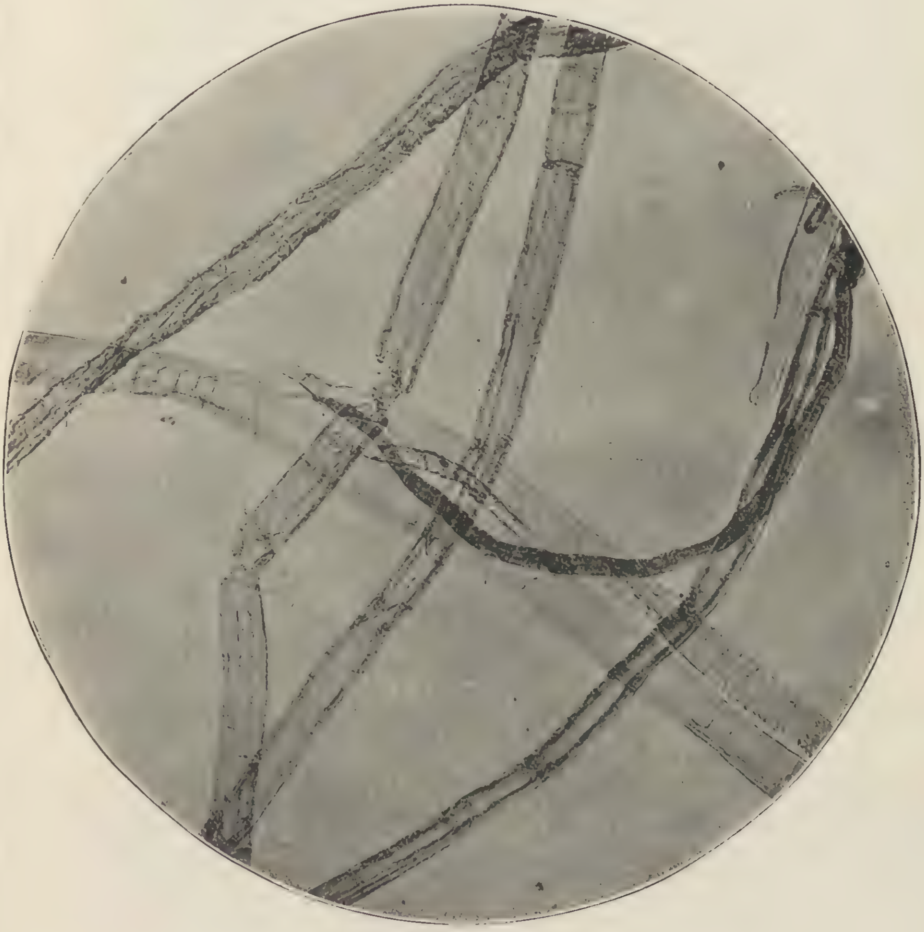
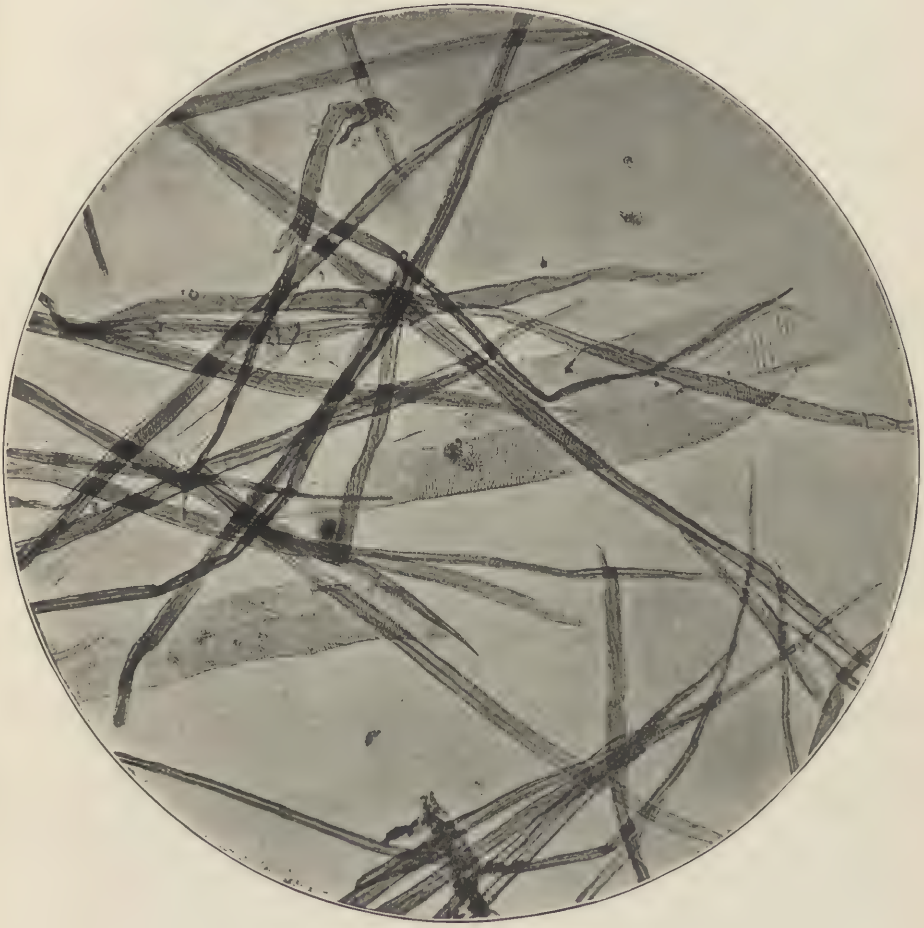
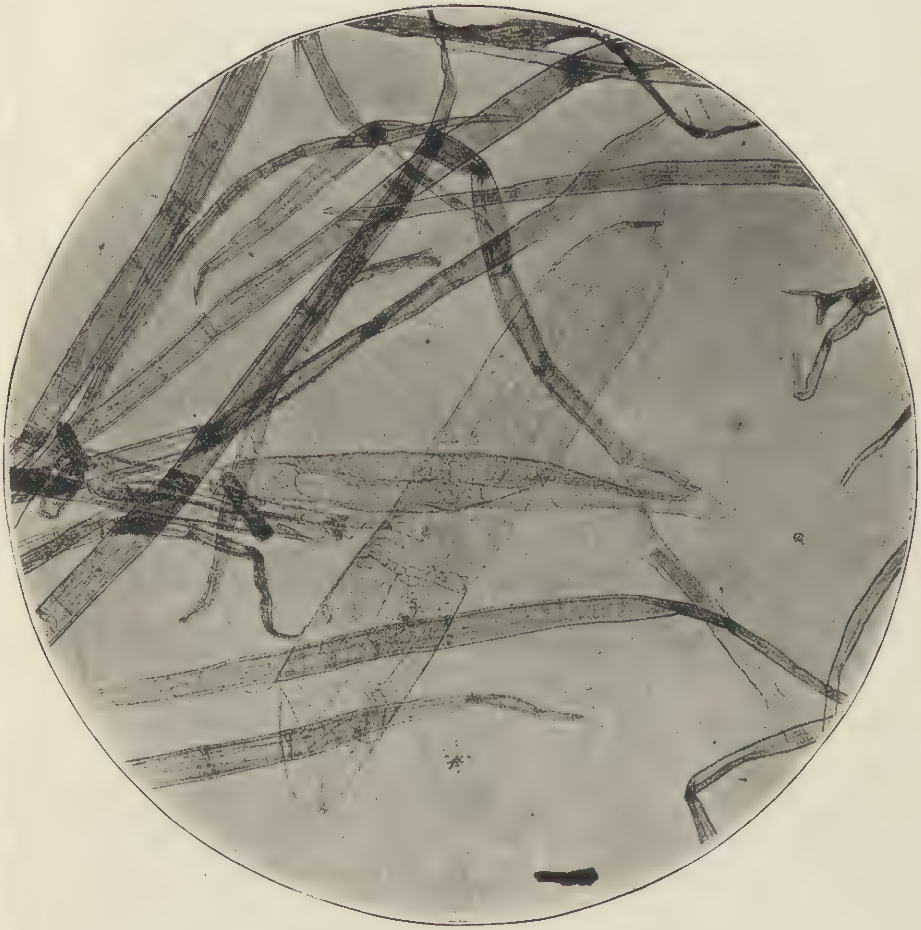


PINE WOOD CELLULOSE



BIRCH WOOD CELLULOSE



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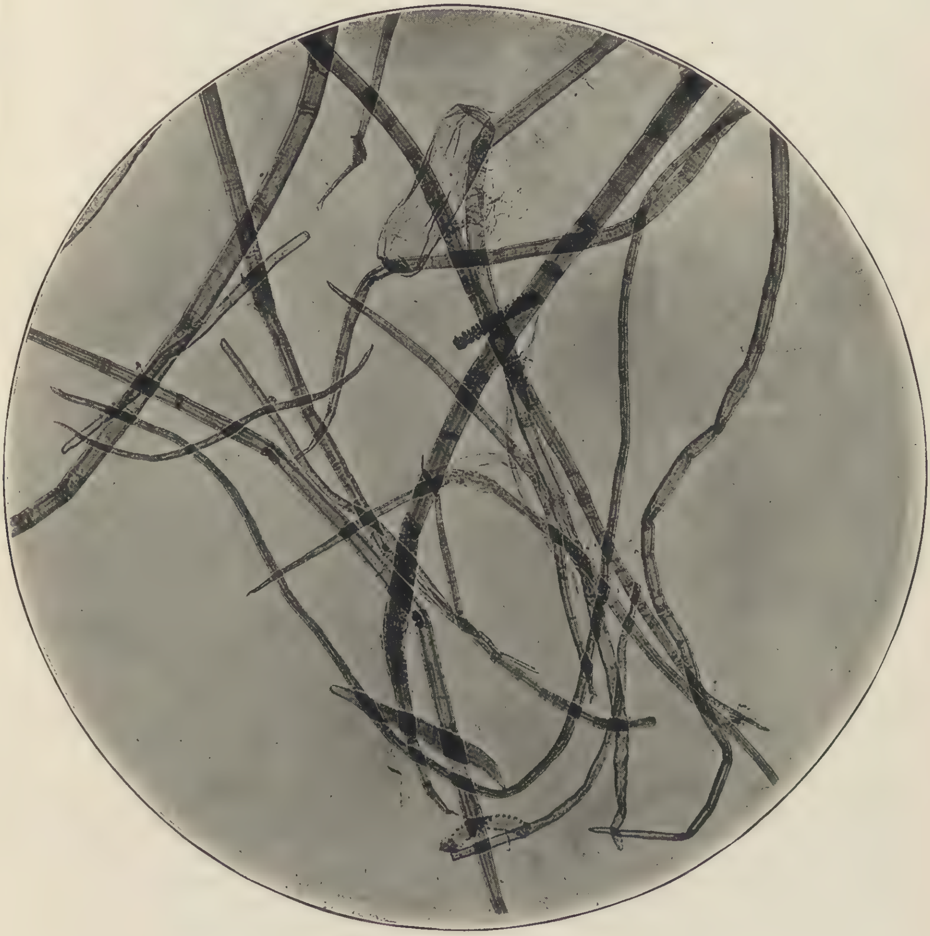

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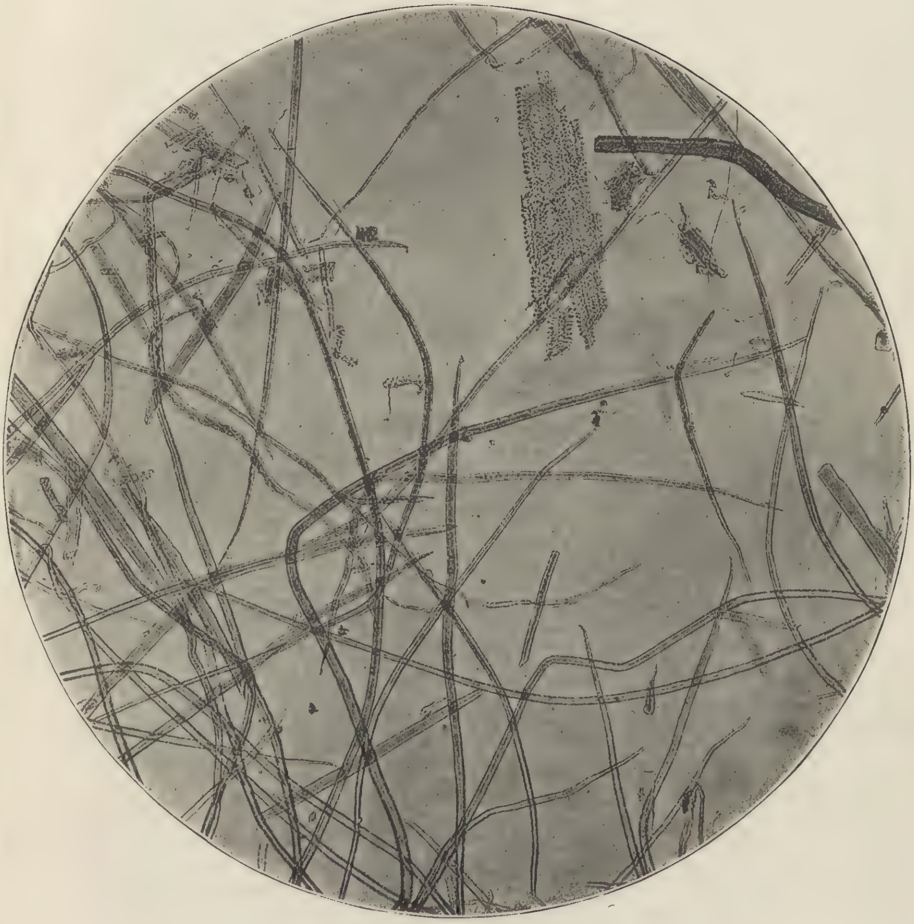

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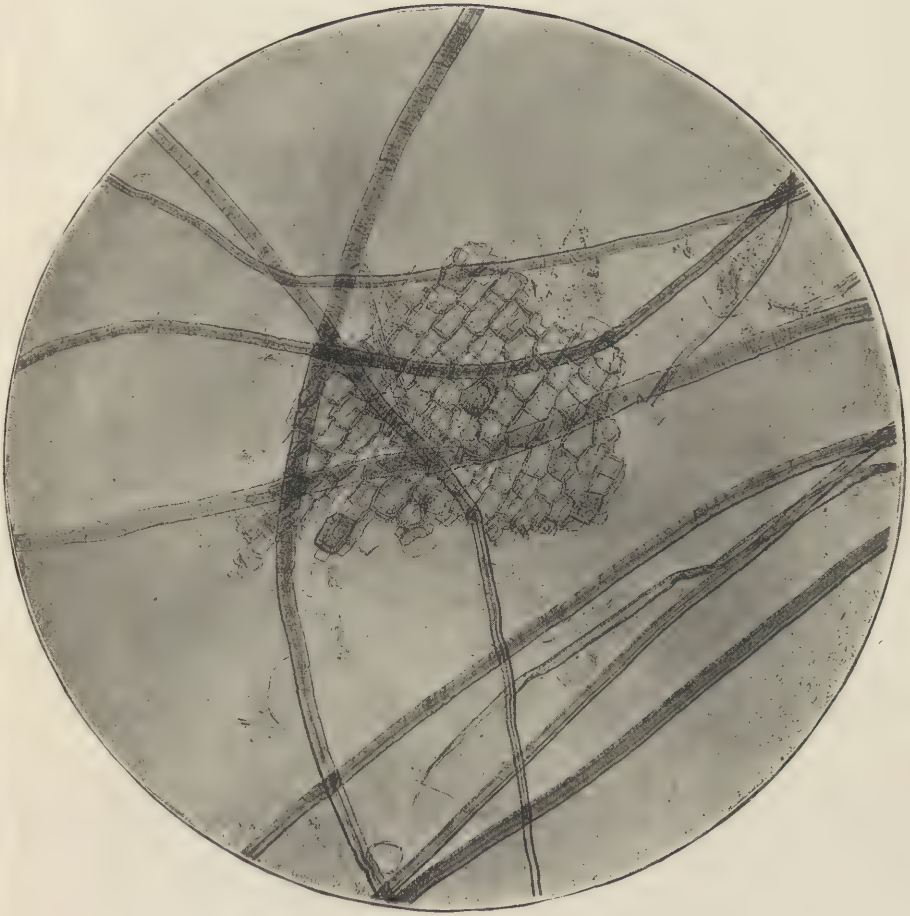

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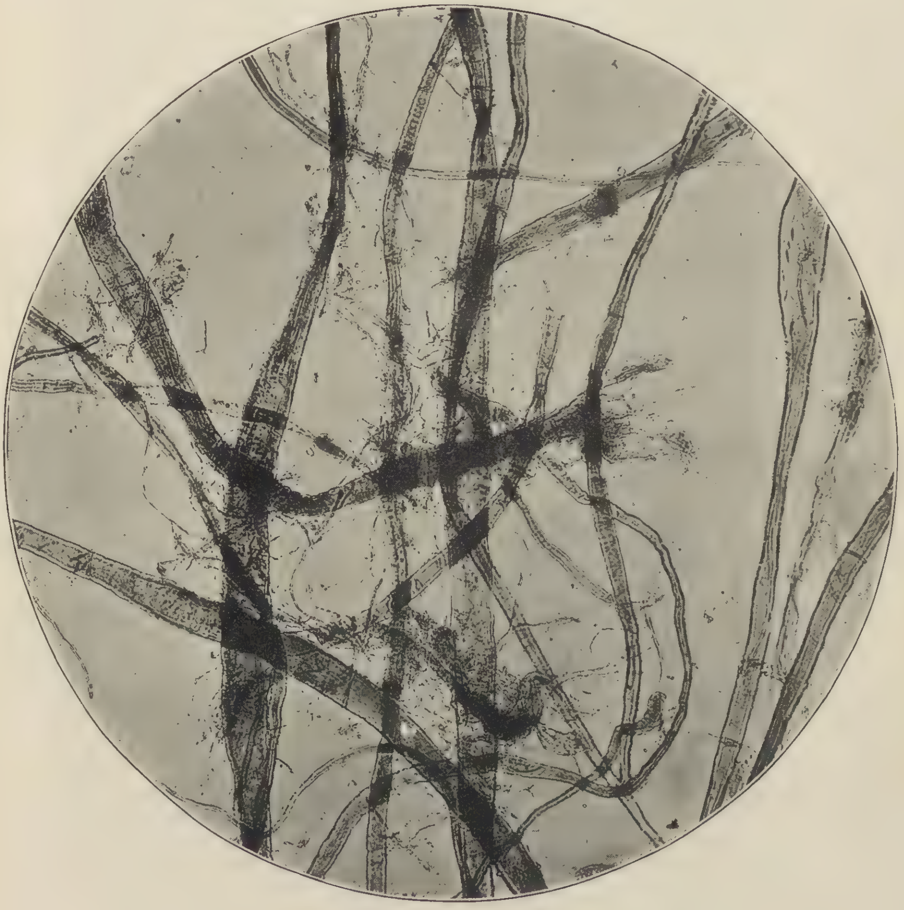

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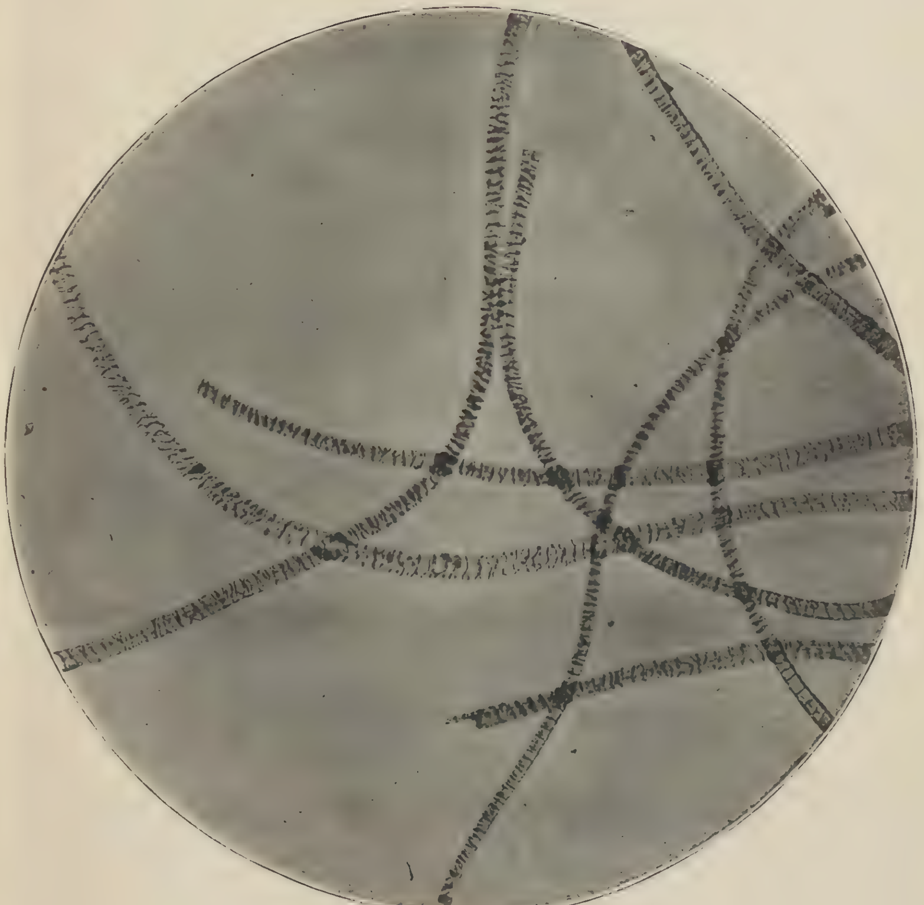

WOOL

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